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PUBLISHERS' ANNOUNCEMENT

Surgical Progress for 1954 is the fourth of an annual series of supplementary volumes to *British Surgical Practice*. It is designed to keep the eight main volumes up to date in an ever-increasing field of surgical knowledge. This is being done in three ways—by original articles, critical surveys and abstracts.

Subscribers to the main work will find reference to this supplementary volume much facilitated by the provision of a "Noter-up" section, and a correct understanding of the method of its use will considerably enhance the value of both the main work and *Surgical Progress*. It will, moreover, save a great deal of time.

Non-subscribers will find the "Noter-up" section of value in that it is alphabetically arranged and gives at a glance information as to the presence or absence of recent material on any particular subject. Consequently, the book can be used independently.

Every article in the main volumes of *British Surgical Practice* has a Key Number, which appears at the commencement of each article and also at the top left-hand corner of every right-hand page. In order to ascertain whether there has been any recent advance in the particular subject to which reference is being made, the reader should merely turn to the appropriate Key Number which appears in the left-hand margin of the "Noter-up" section He will there find either a note that no further references appear or information as to the type of new matter *incorporated by way of article, survey or abstract* This is amplified by a brief outline of the content of the recent addition.

Subscribers who turn direct to the abstract section will find that there also the keyed arrangement has been followed.

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August, 1954.

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NOTER-UP, 1954

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INTRODUCTION

THE SUBJECT matter in the original volumes of *British Surgical Practice* was arranged alphabetically, and it was not easy to ensure that every important subject would be included; had it been arranged anatomically or by systems, the omission of important items would have been less likely to occur. However, we believe that in this Progress Volume for 1954 we have succeeded at last in filling the gaps. Fractures of the Pelvis appeared last year, and now we are adding an article on Injuries of the Bladder and Urethra by Mr. D. S. Poole-Wilson, amplifying the account given in the original work, which was less detailed because it had no direct reference to the whole subject of injuries to the pelvis. In similar fashion the management of Post-Operative Strictures of the Bile-Ducts has been treated comprehensively by Mr. Rodney Maingot, Speech after Laryngectomy has been written by Mr. G. H. Bateman and Mr. V E. Negus; and the treatment of Leprosy has been dealt with by Mr. Paul Brand in a chapter which not only rounds off our original article on Leprosy, but also offers a most stimulating study of finger movements and the benefits to be derived from tendon transplantation and intelligent rehabilitation for finger palsies whatever their cause.

We have attempted to keep the work up-to-date by including the following Two articles on Antibiotics—a general review by Dr. R. A. Shooter, and an appraisal of their value in Bone and Joint Tuberculosis by Dr. F. Harwood Stevenson, a valuable account of the medical and surgical aspects of Poliomyelitis by Dr Ritchie Russell and Mr. H. J. Seddon; a review of current problems in Blood Transfusion by Dr. Geoffrey Tovey and Dr. W d'A. Maycock; a discriminating study of the results of surgery for Carcinoma of the Stomach by Mr. Norman Tanner, and a chapter on Carcinoma of the Oesophagus by Dr. Ross Robertson which, though originally intended as a record of his own method of bringing the jejunum up through the anterior mediastinum to be anastomosed to the cervical oesophagus, has been extended to include personal experience of the various methods of treating oesophageal cancer at different levels and of varying degrees of operability.

In surveying recent advances in surgery we decided to include a chapter on Pelvic Viscerectomy for which we are much indebted to Sir Stanford Cade, an account of the *Surgical Treatment of Involuntary Movements, a difficult subject handled in* masterly fashion by Dr. William Feindel, who is particularly welcome as a colleague of Dr Wilder Penfield and as the author of yet another article from Canada, a well-illustrated article on Tumours of the Glomus Jugulare by Mr F. C. W Capps; and a specialized account by Mr. Hay and Dr Spiers of the Applications of Electronics to Clinical Practice, which we hope may be of value particularly to younger surgeons who may have to handle electronic apparatus in research and in clinical practice. A chapter on the general aspects of Surgery in Korea has been contributed by Major-General Harsant. We hope to publish contributions from specialists in war surgery in future volumes

We feel that we can offer this book to our readers as a substantial contribution to current surgical literature, and we would express to our colleagues the authors of these chapters our warm appreciation of the help which they have so generously given us.

E. ROCK CARLING
J. PATERSON ROSS

INJURIES AND STRICTURES OF THE BILE-DUCTS

By RODNEY MAINGOT, F.R.C.S.
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TRAUMATIC RUPTURE OF THE BILE-DUCTS

Rupture of some portion of the extra-hepatic bile-ducts is a rare complication of trauma to the right upper quadrant of the abdomen or to the lower part of the right chest.

The bile-ducts may be contused, punctured at one spot, partially torn, completely divided, or severely lacerated by *penetrating* or *non-penetrating wounds.*

Gun-shot wounds, stabs, and the like, which traumatize the biliary tree, are frequently associated with multiple visceral injuries. Such organs as the liver, the pyloric end of the stomach, the first two portions of the duodenum, the head of the pancreas and the base of the right lung, are commonly severely ruptured when penetrating wounds involve the right hypochondrium or the lower part of the right chest wall.

On the other hand, *sub-parietal ruptures* of the extra-hepatic biliary tract are rarely associated with local visceral lesions. Up to the present time, 50 cases of sub-parietal rupture of the bile-ducts have been reported in the literature.

Rudberg (1921) recorded a personal case of injury to the choledochus and collected another 40 examples of bile-duct injury.

Lewis (1938) found six additional cases and gave an account of a case which occurred in his own practice upon which two operations proved necessary.

Since then the following three cases have been reported: (1) Complete rupture of the common duct (Lysaght, 1939); (2) injury to the common duct associated with transection of the pyloric portion of the stomach (Grimault, 1947); and (3) rupture of the hepatic duct near the junction of the right and left hepatic ducts (Milnes Walker, 1953).

Aetiology

Sub-parietal rupture of the bile-ducts is always the result of a blow or crush to the right hypochondriac region or to the right costal margin.

Usually this is the only injury, but sometimes there is concomitant damage to adjacent viscera, notably the liver.

Milnes Walker (1953) and others believe that the direction of the force rather than its violence determines whether the ducts are injured Lewis (1938) states that the force must be applied in a direction that will crush the ducts between the liver and the bodies of the vertebrae at that level.

Clinical picture

The initial signs and symptoms vary considerably and depend upon the following (1) The nature of the injury, that is, penetrating or non-penetrating; (2) the direction and the force of the blunt trauma to the right side of the abdomen; (3) the presence or absence of multiple injuries; (4) the escape of bile, loculated in the sub-hepatic region or free to escape into the general peritoneal cavity; and (5) the presence or absence of sepsis.

When the bile-duct and liver are injured, the clinical manifestations will be those of profound shock, recovery from shock, followed by abdominal rigidity and tenderness, pyrexia, and severe intra-abdominal haemorrhage. In less severe cases, however, in which injury to the biliary tract has been the *sole lesion*, there is always some degree of shock, with recovery from shock within a few hours. On examination, a slight degree of abdominal distension, tenderness and rigidity on the right side of the abdomen will be noted, but there may be little to suggest the severity of the lesion.

There is one feature which is almost constant and that is the remission of symptoms after the initial acute catastrophe. The patient may appear to be progressing satisfactorily until conjunctival icterus, a subphrenic mass, or a distended abdomen proclaims the gravity of the condition.

From the first to the twenty-first day following the injury the abdomen slowly distends with fluid and, after a variable period, jaundice will be observed. The jaundice becomes progressively more intense, the stools become clay-coloured, the urine is laden with bile, and fever, exhaustion and wasting are evident. Paracentesis will disclose that there is free bile in the peritoneal cavity, and thus clinch the diagnosis. Gordon-Taylor (1953) has emphasized that every peritonitis of the right hypochondrium following trauma should suggest damage to the biliary tree. Jaundice is said to be present in 65 per cent of injuries to the biliary tract, but in only 5 per cent of injuries to the liver; the presence of icterus is, therefore, of some diagnostic value.

Biliary extravasation is usually intra-peritoneal, but may be retro-peritoneal in its distribution. Following an injury to the bile-duct, the escaping bile may become loculated in the lesser peritoneal sac, or again, it may become entrapped in Morison's pouch, but in most cases it pours freely into the general peritoneal cavity.

Localized collections in the sub-hepatic space may remain dormant for many days or weeks, but they are very prone to rupture following some slight trauma, such as a strain, in which case a severe type of diffuse peritonitis may ensue.

Treatment

As soon as a diagnosis of ruptured bile-duct is made or suspected, the patient should be given a brief but intensive course of pre-operative treatment. This would include intravenous infusions of glucose-saline, blood transfusion, and intramuscular injections of vitamin K and penicillin.

The abdomen is best explored through a lengthy right paramedian or a Kocher's oblique subcostal incision. A localized subphrenic collection, when present, should be evacuated by aspiration, and bile in the peritoneal cavity should be removed by a suction tube. Most of the peritoneal fluid should be withdrawn before proceeding with a rapid, but methodical exploration of the stomach, duodenum, liver, pancreas, hepatic flexure and transverse colon, and biliary tract.

It will be noted that the structures in the vicinity of the bile-ducts are oedematous, adherent and bile-stained.

Adhesions which are glued to the gall-bladder or portal fissure should be gently separated, after which the operative field should be packed off with a long strip of gauze to permit good retraction and exposure of the gall-bladder and biliary passages.

Most of these patients are [illegible] toxaemic, dehydrated and very ill, and any prolonged operation is usual[illegible] question. Nevertheless, after obtaining the maximum exposure with wel[illegible] [illegible]er retractors, a most careful search amidst the bile-soaked friable tissues [illegible] for a re[illegible] duct. The anterior leaf of the right border of the gastr[illegible] [illegible]m mu[illegible] incised and carefully dissected [illegible] order to [illegible] of th[illegible] [illegible] portion of the choled[illegible] cystic duct, [illegible] and [illegible] hepatic ducts at the hi[illegible] [illegible]er. During [illegible] the hepatic artery and its [illegible] be v[illegible]

In some instances, and more particularly in those cases of rupture of the bile-duct associated with a chronic sub-hepatic collection of infected bile, it may be impossible to find the common duct in the scarred leathery tissue overriding the portal vein. It is conceivable that the bile-duct may atrophy or stenose completely when it is immersed in the cytolytic or sclerosant bile for some length of time. In such cases an attempt should be made to isolate the hepatic duct and to anastomose it, by the end-to-side method, to the adjacent first part of the duodenum.

The commonest situation for the tear is high up in the hepatic duct close to the junction of the right and left hepatic ducts. Such lesions are extremely difficult to identify and even more difficult to repair. If the aperture is small, clear-cut, and involves only the anterior wall of the duct, it may be securely closed with a few interrupted through-and-through sutures of fine silk mounted on atraumatic needles, after which the operative field is drained with a strip of corrugated rubber or a Penrose tube.

If, on the other hand, it is impossible to visualize the entire extent of the rent in the hepatic duct it is advisable to make a small incision in the anterior wall of the common bile-duct, in order to explore the ducts beyond with graduated Bakes dilators. If these dilators can be introduced without hindrance into the right and left hepatic ducts and for a short distance beyond where they disappear into the liver, the operation should be completed by inserting a small T-tube into the common duct and by closing the margins of the incision of the common duct about the long issuing limb of the tube.

A few well-placed interrupted sutures of fine silk are finally inserted to close the aperture in the hepatic duct.

Lacerations of the common bile-duct are more easily dealt with as the majority of them are situated in the anterior wall of the duct. They may be longitudinal or transverse, or again there may be a complete transverse or oblique rupture of the duct.

Where the tear involves only the anterior wall of the supra-duodenal portion of the choledochus, it is a simple matter to insert a T-tube through the rent in the duct and approximate the margins of the duct around the issuing limb.

When, however, the duct is completely transected, the ends of the duct should be picked up, freshened and sutured together, without tension, with a single layer of silk sutures. A T-tube is then introduced through a small opening made above or below the suture line, but the long issuing limb of the T-tube is never brought out through the line of anastomosis itself The inlaying portion of the T-tube acts as a splint for the newly-fashioned axial anastomosis and, when it is withdrawn some six to eight months later, it does not inflict any strain or damage to the anastomotic junction

If the lower end of the common duct is badly lacerated, or is difficult or impossible to isolate or to approximate to the upper end, it is better to ligate and invert the proximal end of the duct, and, after ensuring that the cystic duct is patent and free from any kinks, to anastomose the fundus of the gall-bladder, to a portion of proximal jejunum situated about 18–20 inches from the ligament of Treitz.

An entero-anastomosis between the afferent and efferent limb of the jejunal loop is then constructed to deflect the gastric and duodenal contents away from the cholecysto-enteric stoma.

Similar repairs should be attempted on all *penetrating wounds* involving the bile-ducts. It should be remembered that in those cases in which there is considerable loss of substance, the duodenum and the head of the pancreas can be widely mobilized to permit an end-to-end approximation of the severed ducts If this can be accomplished, the common duct should always be drained by means of a T-tube.

The following points are worthy of emphasis

(1) The operative field should always be drained with a rubber or Penrose tube or

with sheets of corrugated rubber. These tubes are left in place for three or four days.

(2) T-tubes should be left *in situ* for a period of six to eight months. They should be irrigated daily with a few ounces of warm sterile saline solution. The long arm of the T-tube should drain continuously (into a small bottle fixed to the side of the bed) for at least three weeks before it is clamped for brief periods during the day. When the patient is discharged from hospital, the tube is "spigoted" and strapped to the side of the belly with adhesive tape. Before the T-tube is removed it is advisable to have x-ray evidence, by means of choledochograms, that the bile-ducts are amply patent. T-tubes do not damage the bile-ducts and they are not, in themselves, responsible for any subsequent stricture formations.

(3) All anastomoses, whether these be duct to duct or duct to intestine, should be mucosa-to-mucosa unions. There should be no tension on the suture line.

Prognosis

The older records show a high case-mortality and a high case-morbidity.

A study of the case reports shows that many patients were treated by repeated paracentesis, or by external biliary drainage. A few of the latter cases developed a chronic external biliary fistula, which, after a variable period, was "cored out" and "implanted" into the stomach or duodenum, with disastrous results.

In some instances the rent in the duct was found and sutured, whilst in others axial unions were carried out *without* the aid of T-tubes or any type of inlay. The majority developed post-operative strictures of the bile-ducts and had to be subjected to one or more reconstructive procedures.

Taken as a whole, the immediate and late results were discouraging, although there were a few notable successes at the first attempt. A determined effort should be made to ensure that one operation will suffice.

INJURIES DURING OPERATION, AND POST-OPERATIVE STRICTURES

Aetiology

Over 80 per cent of the recorded cases of benign stricture of the extra-hepatic biliary tract follow cholecystectomy for calculous cholecystitis; 10 per cent after operations upon the ducts themselves, and 3 per cent after gastro-duodenal resection for chronic penetrating duodenal ulcer. These are the man-made strictures, a complication which has arisen in the evolution of biliary tract surgery.

We are not concerned here with the remaining 7 per cent of benign strictures, which include: (1) Congenital obstruction or atresia of the bile-ducts; (2) strictures which result from external violence; (3) sclerosing cholangitis; (4) chronic fibrosing pancreatitis; (5) ulceration of the wall of the common bile-duct due to stone or chronic duodenal ulcer; and (6) choledochus cyst.

Surgical accidents are, therefore, by far the most common cause of benign strictures of the bile-ducts. The results of such misadventures during operations upon the gall-bladder, bile-ducts, duodenum, pancreas, liver and the hepatic flexure of the colon, are tragic, and every conceivable precaution should be taken to avoid them.

The tragedy of such surgical misdemeanours will be appreciated when it is realized that 70 per cent of these unfortunate patients are women who are under the age of 50, and that less than 50 per cent of these are eventually completely cured. In other words, one-half of the patients who sustain an injury to the biliary tract during operation succumb to the initial procedure either during the immediate post-operative period or at some time later following one or more attempts to establish the flow of bile into the intestinal canal. It is impossible to determine the *incidence*

owing to the dearth of statistical data on the subject except from large institutions in America. For obvious reasons, these statistics are not truly representative of the general experience.

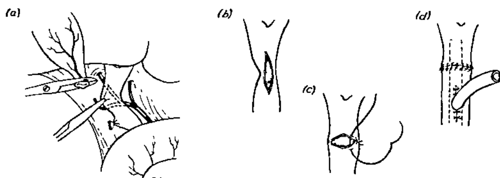
Howard Gray (1951), who reviewed 700 operations for biliary tract reconstruction, believes that post-operative strictures of the ducts are increasing in frequency, and this view is supported by Waugh (1952), who writes: "In 1951 there were 83 such cases *at the Mayo Clinic, a 46 per cent increase over the total of 1950.*"

Lahey and Pyrtek (1950) reported a consecutive series of 314 cases, and Cattell (1953) in reply to a letter states: "We have had 25 strictures on our service in the past two months. We have operated upon well over 400 patients with strictures of the bile-ducts which resulted from previous biliary tract procedures. We did 102 in 1951–1952, and so far this year we have done 60."

O'Malley and his colleagues (1951) reported on 54 patients who had had operations for post-operative stricture.

At the meeting of the Association of Surgeons of Great Britain and Ireland, held in London on May 1st, 1953, Professor Wells, of Liverpool, gave his experiences in the management of 18 patients upon whom he had operated for post-operative strictures of the extra-hepatic bile-ducts; Dickson Wright reported 10 cases, and the writer analysed the results he obtained following operation upon 27 patients. On that occasion a tribute was paid to the British pioneers in this field and special reference was made to the excellent papers on this subject by Walton (1944) and Grey Turner (1944). Since that meeting, the writer has had further experiences with 16 cases which have been referred to him for operative correction.

The following remarks are based on the personal management of 43 cases of post-operative stricture, many of which had had one or more unsuccessful reconstructive procedures performed elsewhere.



Fi

in situ for about 8 months.

Classification of the causes of post-operative stricture of the bile-ducts

(1) Poor exposure of the operative field.

(2) Over-confidence, carelessness; haste.

(3) A lack of anatomical knowledge and of the appreciation of anomalies of the bile-ducts and the cystic artery.

(4) Haemorrhage from the cystic artery, an accessory cystic artery, or the right hepatic artery (Fig. 1*a*).

(5) Undue traction on the mobilized *gall-bladder and the* application of a clamp and ligature to the taut and angulated main bile-ducts (*see* Fig. 2*a*).

(6) Mutilation of the duct in exploring it *for stones.*

(7) The formation of a false passage (*or passages*) between the choledochus and duodenum by means of sounds, dilators and the like, in *cases of fibrosis of the* sphincter of Oddi or sclerosing *pancreatitis.*

(8) Suturing the cut edges of *the gastro*-hepatic omentum too tightly over the common bile-duct after *cholecystectomy*, choledochostomy, or cholecystectomy combined with T-tube drainage of the choledochus.

(9) Partial or complete occlusion of, angulation of, or injury to the lower end of the common bile-duct during the *process* of excising a large, adherent, duodenal ulcer, or excessive inturning of the *duodenal* stump during the performance of partial gastrectomy.

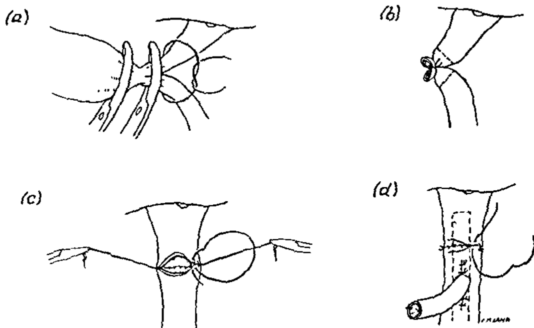


Fig. 2.—Ligation of the common bile-duct and hepatic duct during retrograde cholecys- [illegible] the ducts may [illegible] bladder; [illegible]

(10) Injury to the lower reaches of the bile-duct during excision of a pulsion diverticulum of the second portion of the duodenum.

(11) A segment of the bile-ducts may be excised or incised during wedge *resection* of the liver for cancer of the gall-bladder, or during a block resection of a hard mass involving *the hepatic flexure of the colon,* the great omentum, the gall-bladder and a portion of the right lobe of the liver. Such a mass may be produced by an adherent *carcinoma* of the colon, or even by calculous cholecystitis, in which the gall-bladder has been the seat of repeated attacks of acute inflammation, with local gangrene, perforation and abscess formation.

(12) The packing of gauze in the oozing bed of the gall-bladder to be left *in situ* and removed through the wound may be the cause of a subsequent obliterative [illegible] to control haemorrhage [illegible] the [illegible]

(13) The pooling of the [illegible] -do- chostomy, trans-duodenal choledochostomy or the "blowing-out" of the duodenal

stump shortly after the performance of gastro-duodenal resection for peptic ulcer.

Such pooling of bile, which on becoming infected leads to a sub-hepatic abscess, *may result from: (a) Slipping* of the ligature which had been applied to the cystic duct; (*b*) inadvertent early withdrawal or displacement of a T-tube; (*c*) discharge of bile from an uncovered gall-bladder fossa; (*d*) unrecognized severence of an accessory hepatic duct; or (*e*) kinking or blockage of a drainage tube or a T-tube.

In these cases a sub-hepatic collection may form and be responsible for sclerosing cholangitis, or the continuous immersion of the bile-ducts in the irritating constituents of the cytolytic bile may lead to a widespread fibrotic contraction, or even obliteration, of the extra-hepatic biliary passages.

The main causes of post-operative stricture are poor exposure of the field of operation, haemorrhage from the cystic or right hepatic artery, and sclerosant effect of pent-up bile in the region of the bile-ducts.

Difficulty of access is often due to an inadequate or badly placed incision, a poorly administered anaesthetic, inefficient illumination, and the incorrect position of retractors Complete, minute, unequivocal *visualization* of every single anatomical structure in the operative field is the keynote of success in biliary tract surgery. Good access also demands methodical, cautious and studied progress, as well as meticulous dissection Was it not Moynihams (1928) who said that the surgeon should work by sight and not by faith?

It is frequently stated that abnormalities in the origin, course, length and distribution of the cystic artery or of the right hepatic artery, are important predisposing causes, but it is the surgeon's duty to be familiar with these variations and to recognize them at operation whenever they are present.

An intimate knowledge of anatomy learned from text-books and in the anatomy room will prove no safeguard to the rash or over-confident surgeon who, on occasion, has to operate upon the distorted and seemingly inaccessible "pathology of the living".

When the parts concerned in the operation have not been clearly visualized, excision of the gall-bladder is always a hazardous undertaking. In some cases of acute calculous cholecystitis the important structures in the right border of the gastro-hepatic omentum may defy identification owing to the marked degree of inflammatory oedema and/or fibrosis which are present.

If, after a preliminary dissection, cholecystectomy is deemed too hazardous, it is wiser to drain the viscus, after completely emptying it of its contents.

Post-operative stricture is a relatively rare sequel of excision of the gall-bladder for acute cholecystitis (in 10 per cent of all cases). A long gall-bladder with a mobile mesentery in a visceroptotic patient—the easy case—and an over-confident surgeon lacking in technical skill, constitute the most sinister combination.

One of the chief causes of bleeding from the cystic artery is undue traction upon the mobilized gall-bladder. This traction is applied, not to the cystic duct, but to the cystic artery

When the cystic artery snaps as the result of forcible traction, or is divided during a "blind" dissection, the short stump of the vessel immediately retracts and bleeds copiously in its hidden retreat beneath (or, more rarely, above) the hepatic duct. The cystic artery, too, when clipped with large curved haemostats, may slip through the serrated and clumsy blades, or it may even be avulsed when the forceps which grasp it are sharply pulled upon by a careless assistant. Artery forceps, with fine sharp serrations, may actually bite through the cystic artery and thus produce troublesome haemorrhage

Bleeding from the cystic artery or from the distal end of the right hepatic artery (Figs. 1*a* and 3), a pool of blood and a blind plunge with a clamp for the briskly spurting point, will often lead to a number of tragic events.

Lahey (1948) described another cause of arterial haemorrhage during retrograde cholecystectomy as follows.

"I wish particularly to warn against a quite commonly employed method of doing cholecystectomies, and that is the placing of a single clamp on the cystic duct so as to include the cystic artery. Not infrequently, as one pulls upon the gall-bladder, traction upon the cystic artery will so angulate the right hepatic artery that, as the clamp is placed upon the neck of the gall-bladder, it will include the angulated right hepatic artery. This places the artery under tension so that, as the tie is placed across the knuckle of artery, there is a tendency for the upper arterial end to retract out of the ligature and result in a serious haemorrhage" (*See Fig* 3.)

Haemorrhage is the most common cause of injury, particularly to the hepatic duct. When such bleeding occurs during excision of the gall-bladder, it is an easy matter to arrest the haemorrhage and to visualize the end of the culpable vessel by compressing the hepatic artery between the index finger and thumb of the left hand at the free margin of the gastro-hepatic omentum, as originally advocated by Seton Pringle. The blood should then be removed by suction and sponging with gauze swabs. The end of the bleeding vessel should be carefully isolated, clamped and ligated.

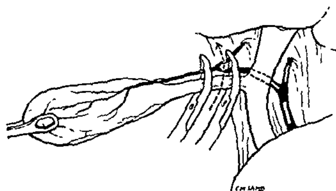


Fig. 3.—Illustrating risk of placing a single clamp on the cystic duct and "cystic" artery.

A relatively common factor leading to common duct injury is angulation of the common and hepatic ducts by the application of too much outward traction on the gall-bladder and inadequate downward traction on the supra-duodenal portion of the common duct by an assistant. In such circumstances, the angulated common duct may be mistaken for the distal end of the cystic duct and a ligature may be applied around the two main ducts as illustrated in Fig. 2*a* and *b*. If this type of accident is not recognized and corrected at the time of operation, it produces immediately post-operative symptoms of: (1) obstructive jaundice; (2) bile peritonitis; or (3) external biliary fistula.

If the haemostat and ligature only partially occlude the common duct, symptoms of cholangitis may not appear for months or years after operation, when stenosis develops at the site of the partial ligation. It is difficult to account for those cases in which a large segment of the bile-duct has been removed *en masse* with the gall-bladder.

A study of the operation notes, or a description of the original procedure by the surgeon in charge of the case is, as a rule, unsatisfactory. Less than 5 per cent of all the cases of injury to the bile-ducts are recognized during the performance of the primary operation.

A rare type of injury to the common duct, which can result in stricture, is mutilation of the duct in the process of exploring it for stone or benign stricture of the ampulla of Vater.

The walls of the duct may be torn, or severely crushed, by too forcibly applying

and reapplying Allis or other forceps which have teeth, or by the tearing out of stay sutures when they are unduly dragged upon to aid in the retraction of the margins of the duct. Long, slender Allis forceps, from which all teeth are removed, are now often employed in common duct surgery.

Another infrequent cause of stricture is the peritonealization of the choledochus, or rather, the over-zealous suturing of the margins of the gastro-hepatic omentum over the denuded ducts, thereby producing an obstruction.

Following cholecystectomy, the ligature on the cystic duct may slip off and, if the escaping bile collects in the sub-hepatic area, it may become infected. If an abscess forms and is not drained efficiently, it is possible that the resulting fibrosis may involve a wide segment of the bile ducts in contracting scar tissue, with grave results.

Fibrosis, leading to obliteration of the bile-ducts, may be due to sclerosing agents in the bile acting *from without*, rather than to some process acting within the ductal system, or to impairment of the blood supply to the biliary passages.

PRECAUTIONS IN BILIARY TRACT SURGERY

The prevention of stricture of the bile-ducts is dependent upon many factors, which include: (1) Complete muscular relaxation; (2) good exposure; (3) complete haemostasis, (4) ligation of the cystic artery before ligation of the cystic duct; (5) careful dissection which displays the cystic duct at its point of junction with the common bile-duct and the hepatic duct; (6) a search for anomalous cystic arteries and accessory ducts, (7) removal of the gall-bladder from above rather than from below in cases of acute cholecystitis; (8) the avoidance of undue traction upon the gall-bladder; (9) putting the common bile-duct on the stretch during excision of the gall-bladder or during exploration of the bile-ducts, (10) peritonealization of the denuded gall-bladder fossa; and (11) drainage of the operative field. T-tubes should be kept securely in position until they are no longer required for drainage, irrigation, or moulding purposes.

If this type of accident is recognized *at the time of operation* it should be corrected immediately, otherwise the patient will develop obstructive jaundice, bile peritonitis (with or without "pocketing" in the subphrenic space, pelvis or elsewhere in the peritoneal cavity) or an external biliary fistula. The possibility of stricture of the bile-ducts should be entertained in all patients who, following operations upon the biliary tract or duodenum, develop symptoms of obstructive jaundice. In some instances, the onset of icterus may be delayed for months or years after operation.

MANAGEMENT OF POST-OPERATIVE STRICTURES OF THE BILE-DUCTS

Pre-operative treatment

This should be short but intensive. The diet should be rich in proteins and carbohydrates, but low in fats. Intravenous injections of salt, glucose and vitamins, including vitamin K, are given. Prothrombin times are determined to evaluate bleeding tendencies and vitamin K deficiency.

Blood transfusions are given before, during and after operation, and routine hepatic and renal function tests are carried out in assessing the operative risks.

Operative principles

(1) If the surgeon recognizes or suspects that the common bile-duct or the hepatic duct has been injured during the course of an operation, he should make every attempt at an immediate repair.

Lahey (1948) described another cause of arterial haemorrhage during retrograde cholecystectomy as follows.

> "I wish particularly *to warn* against a quite commonly employed method of doing cholecystectomies, and that is the placing of a single clamp on the cystic duct so as to include the cystic artery. Not *infrequently*, as one pulls upon the gall-bladder, traction upon the cystic artery will so angulate the right hepatic artery that, as the clamp is placed upon the neck of the gall-bladder [illegible] places the artery under tension [illegible] there is a tendency for the uppe[illegible] a serious haemorrhage." (*See* F[illegible])

Haemorrhage is the most common cause of injury, *particularly to the hepatic duct*. When such blood [illegible] artery between the index finger and thumb of the left hand at the free margin of the gastro-hepatic omentum, as originally advocated by Seton Pringle. The blood should then be removed by *suction* and sponging with gauze swabs. The *end* of the bleeding vessel should be carefully isolated, clamped and ligated.

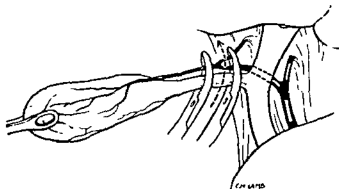


Fig 3.—Illustrating risk of placing a single clamp on the cystic duct and "cystic" artery.

A relatively common factor leading to common duct injury is angulation of the common and hepatic ducts by the application of too much outward traction on the gall-bladder and inadequate downward traction on the supra-duodenal portion of the common duct by an assistant. In such circumstances, the angulated common duct may be mistaken for the distal end of the cystic duct and a ligature may be applied around the two main ducts as illustrated in Fig. 2*a* and *b*. If this type of accident is not recognized and corrected at the time of operation, it produces immediately post-operative symptoms of: (1) obstructive jaundice; (2) bile peritonitis; or (3) external biliary fistula.

If the haemostat and ligature only partially occlude the common duct, symptoms of cholangitis may not appear for months or years after operation, when stenosis develops at the site of the partial ligation. It is difficult to account for those cases in which a large segment of the bile-duct has been removed *en masse* with the gall-bladder.

A study of the operation notes, or a description of the original procedure by the surgeon in charge of the case is, as a rule, unsatisfactory. Less than 5 per cent of all the cases of injury to the bile-ducts are recognized during the performance of the primary operation.

A rare type of injury to the common duct, which can result in stricture, is mutilation of the duct in the process of exploring it for stone or benign stricture of the ampulla of Vater.

The walls of the duct may be torn, or severely crushed, by too forcibly applying

and reapplying Allis or other forceps which have teeth, or by the tearing out of stay sutures when they are unduly dragged upon to aid in the retraction of the margins of the duct. Long, slender Allis forceps, from which all teeth are removed, are now often employed in common duct surgery.

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Operative principles

(1) If the surgeon recognizes or suspects that the common bile-duct or the hepatic duct has been injured during the course of an operation, he should make every attempt at an immediate repair.

(2) If it is at all possible to perform axial anastomosis, that is, [illegible] always be made for the retro-duodenal portion of the common bile-duct. This can often be identified and isolated by completely mobilizing the first and second parts of the duodenum and by *carefully dissecting* the tissues which over-ride the antero-superior aspect of the head of the *pancreas*. Whenever conditions permit, as soon as the undamaged portion of the common duct is liberated it should be anastomosed (over one arm of a T-tube) to the divided stump of the hepatic duct.

(4) *When employing* a T-tube, for splintage and drainage purposes following end-to-end union of the ducts, it is important not to bring the long limb of the tube out at the line of anastomosis but through an incision made in *the anterior wall of the* duct, either above or below this point, so that its subsequent removal will not damage the suture line (Fig. 4).

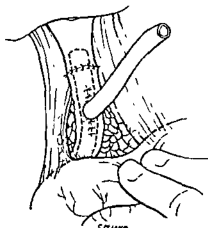


FIG 4.—Choledocho-choledochostomy. The lower end of the common duct has been isolated from head of the mobilized pancreas and anastomosed to the hepatic duct. T-tube choledochostomy completes the operation

(5) In those strictures in which it is impossible to find or to utilize the retro-duodenal segment of the common duct, it is better to anastomose the common or hepatic duct to a loop of proximal jejunum than to the duodenum (Fig. 5). Where such a loop is used, an entero-anastomosis should be made to by-pass the food and gastro-duodenal juices away from the biliary tree. By this plan, ascending cholangitis is prevented or, at least, mitigated. The Roux-Y method of anastomosis has many supporters (Fig. 7).

(6) The anastomosis must be made accurately and without tension. As a rule, a fine continuous chromic catgut stitch is used for the inner layer, whilst the outer layer consists of interrupted sutures of fine silk or cotton. Many surgeons prefer a single row of through-and-through interrupted sutures for fashioning the anastomosis. The mucosa should be approximated to the mucosa. This may be the mucosa of the approximated duct portions, or may be the mucosa of the duct to the mucosa of the jejunum.

(7) Longmire's operation (Fig. 8) should be the chosen procedure when, in spite of an assiduous and protracted dissection of the structures of the hilum of the liver, no portion of the hepatic ducts can be found.

The coring-out or coning-out of a biliary fistula, and the implantation of such a fistulous tract into the stomach, duodenum or jejunum, is doomed to failure.

Restoration of bile-duct continuity with the aid of vitallium, polyethylene, or other tubes, when, owing to the shortness of the remaining stump of the hepatic duct, it is impossible to make a direct anastomosis between the ends of the duct, is an interesting study in biliary tract surgery. Such methods of "bridging the gap" have, of course, no place in the modern management of the bile-duct strictures.

IMMEDIATE REPAIR OF DUCT INJURIES

The best results follow immediate recognition of the injury and immediate repair of the ducts. Injuries which are recognized shortly after operation should be repaired as soon as the condition of the patient permits.

TABLE I

IMMEDIATE REPAIR OF DUCT INJURIES

Type of injury	*Type of repair*
Longitudinal or transverse incision in anterior or lateral wall of duct.	Insert T-tube through the incision and close the margins of the duct around it.
Transection of the duct without crushing.	End-to-end anastomosis Insert T-tube above or below anastomotic line.
Hepatic and common ducts have been angulated and clamped, and both proximal and distal ends are completely ligated (Fig 2*a*)	*Resect ducts beyond crushed and ligated area* Perform end-to-end anastomosis (Fig. 2*b, c, d*).
Common duct has been divided close to the superior border of the duodenum.	Mobilize the duodenum and head of the pancreas, and then perform axial anastomosis (Fig 4)
Common duct has been damaged by division or occlusion during gastro-duodenal resection	Perform choledocho-duodenostomy

TECHNIQUE OF EXPOSURE AND REPAIR OF POST-OPERATIVE BILIARY TRACT STRICTURES

Exposure

The scars of previous vertical epigastric incisions should be excised and the incision extended to give adequate exposure. Kocher's incision will afford the best access to the ductal system in obese patients. Where possible, vertical incisions should be excised and extended upward to the costal margin and downward to a point at least 3 inches below the umbilicus. The omentum and abdominal viscera must be carefully freed from the abdominal wall. The omentum, hepatic flexure of the colon, the stomach and duodenum are, as a rule, densely adherent to the undersurface of the liver and must be freed before proceeding with the operation. The main dissection should commence by liberating the omentum and colon along the anterior margin of the liver on the right side, and, after retracting these structures in a downward direction away from the operative field, the foramen of Winslow should be located and exposed.

At this stage, the pyloric end of the stomach and first portion of the duodenum will be seen to be firmly anchored to the gall-bladder fossa and the hilum of the liver. By sharp dissection, the duodenum and pylorus are cautiously dissected away from the hilar structures and gall-bladder bed and drawn downward with a Deaver or Harrington retractor. Frequently during this operation, a small hepatico-duodenal fistula is found, "taken down", and the aperture in the duodenum closed by a series of interrupted sutures inserted transversely in the gut. The pancreatic and retro-duodenal portions of the common duct seldom are damaged by surgical trauma and rarely are strictured unless sclerosing pancreatitis or suppurative cholangitis has been present Whenever conditions permit, every effort should be made to find the lower end of the duct and to anastomose it with the top end.

After the [illegible] en dissected away [illegible] duodenal vessels [illegible] d portion of the

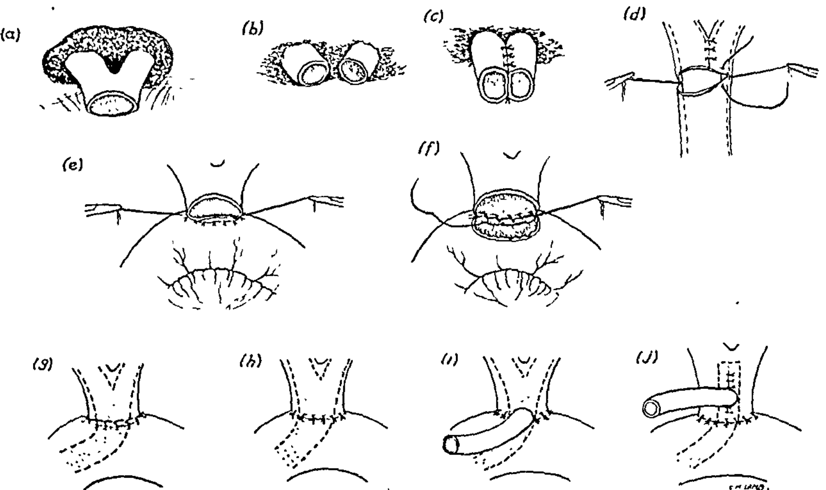


FIG. 5.—Hepatico-jejunostomy or hepatico-duodenostomy. (*a*) Remnant of hepatic duct dissected free from hilum of liver and anastomosed to the duodenum or jejunum (*e*), (*f*), (*g*), (*h*); (*b*) right and left hepatic ducts isolated by fulgurating out, with the coagulating current loop, segments of the liver about the intra-hepatic portion of the hepatic duct until the anterior aspects of the ducts are visible; (*c*) adjacent margins of hepatic ducts sutured together. The septum between the ducts may be divided, as in the Mikulicz operation. Note that Y-tubes or T-tubes may be used, as illustrated in (*g*), (*h*), (*i*) and (*j*). Anastomosis of the remnant of the hepatic duct may be possible (*d*) (*After Lahey*).

duodenum is mobilized by dividing the peritoneum along its superior and right borders. The first and second portions of the duodenum and the head of the pancreas are mobilized posteriorly and lifted free from the inferior vena cava and aorta, care being taken to minimize bleeding and to avoid injuring the thin posterior wall of the duodenum.

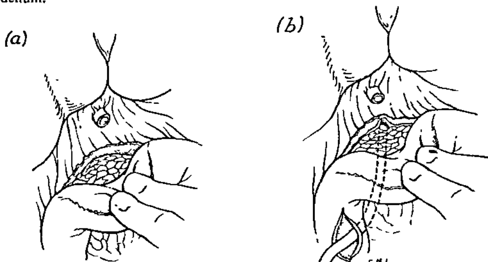


FIG 6—Recovery of the lower end of the common bile-duct by trans-duodenal [illegible]

duct and tip of catheter resected The catheter is pushed upward into the proximal end of the hepatic duct The duodenum and pancreas are advanced toward the hilum of the liver to permit the ends of the duct to be anastomosed with interrupted sutures of fine silk The catheter is anchored to the duct with one catgut suture [illegible]

The common duct lymph-node, the portal vein and hepatic artery are identified and clearly visualized during the dissection which is carried out to isolate the lower end of the common bile-duct. The common duct usually will be found to be buried in the dense fibro-fatty tissue at a point exactly between the common duct node below and the main hepatic artery above. This lymph node is an important landmark in the surgery of ductal reconstruction.

When the lower end of the duct cannot be found proximal to the head of the pancreas, it is advisable to turn the mobilized duodenum over medially and to make an incision through the pancreatic substance parallel to and for a short distance from the medial border of the bowel. As soon as the lower undamaged segment has been discovered, it is isolated from the pancreas and from the surrounding fibrotic tissue proximal to the pancreas until the point of stricture is reached. A sizeable length of patent and healthy duct frequently can be "recovered" and, on account of the mobilization of the duodenum and pancreas, can be elevated to meet the proximal end where an axial union over a T-tube can be performed (Fig. 4). Such an anastomosis is desirable because it preserves the sphincter of Oddi and protects the patient against ascending infection If such an anastomosis is not a feasible undertaking, then hepatico-jejunostomy combined with lateral jejuno-jejunostomy should be carried out. Occasionally Dragstedt's method may be employed with success (Fig. 6).

Whilst emphasis has been placed on the finding and utilizing of the lower end of the duct, it is well known that the identification and isolation of the proximal end at or

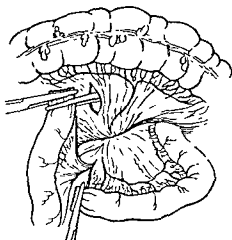


FIG. 7.—Roux-Y anastomosis for high common duct strictures. It is necessary to emphasize that the distal end of the ascending limb of jejunum must

about the hilum of the liver, is the most important, difficult and hazardous part of the operation. The bulbous end of the hepatic duct is often encased in scar tissue, and the hepatic artery and the portal vein itself are always firmly adherent to the remnant of duct.

These vital vessels will have to be dissected away from the duct with a knife or scissors, before resorting to aspiration with a long needle.

In some of the extensive injuries where at operation the common duct cannot be demonstrated, it is advisable to fulgurate out, with the coagulating current loop, segments of liver above and about the intra-hepatic portion of the hepatic duct until the anterior aspect of the duct (or ducts) is visible (Fig. 5*a*).

The two intra-hepatic ducts are cleared of liver tissue by blunt dissection for an inch or so, and, after controlling haemorrhage by means of diathermy, they are then sutured together to form one tube (Fig. 5*b* and *c*).

After dividing the septum between the sutured right and left hepatic ducts, the single mouth is anastomosed to a loop of proximal "defunctioned" jejunum, or to the

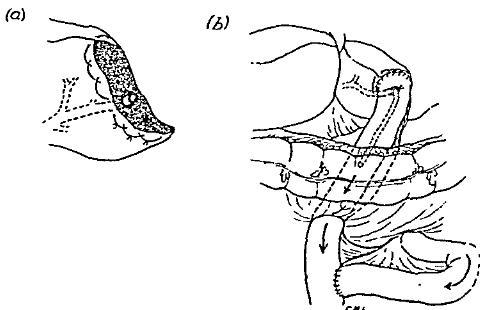


FIG. 8—Longmire's operation. This operation is indicated when the surgeon is unable to locate an extra-hepatic bile-duct at the hilum of the liver or to find an intra-

TABLE II
REPAIR OF BILIARY TRACT STRICTURES

Type of stricture	*Type of repair*
Partial stricture of the common or hepatic duct (Fig. 1*b*).	Heineke-Mikulicz type of repair. Make a long vertical incision through the strictured zone and repair duct as depicted in Fig 1*c* and *d*. Note the position of the T-tube.
Partial stricture of the common or hepatic duct	If scar tissue in the wall of the duct is very dense, it may be advisable to excise the fibrotic segment of duct and perform end-to-end anastomosis (Fig 2*d* and Fig 4)
Stump of hepatic duct can be identified and isolated, but *supra-duodenal portion* of common bile duct cannot be found The lower undamaged end, however, can be discovered by splitting the head of the pancreas, as described	Perform end-to-end duct-to-duct anastomosis over a T-tube (Fig 4)
Hepatic duct or supra-duodenal portion of common duct undamaged, but lower end of choledochus cannot be found or is fibrotic or unsuitable for anastomosis to upper end.	Perform choledocho-jejunostomy or hepatico-jejunostomy with the aid of an inlaying Y-tube (Fig 5*g*, *h*, *i*) or T-tube (Fig 5*j*)
Localized stricture of ampullary region, patient in poor condition.	Perform lateral (vertical) choledocho-duodenostomy.
Localized stricture of the ampullary region, patient in good condition	Perform transduodenal choledochostomy, insert Cattell long T-tube in choledochus, the lower arm of which passes well into the duodenum Close opening in duodenum transversely
Extensive stricture of common duct, but stump of hepatic duct found and isolated in hilum of liver	Choice of 3 operations — (*a*) Hepatico-jejunostomy by Roux-Y method, with mucosa-to-mucosa anastomosis (Fig 7) (*b*) Hepatico-jejunostomy employing long "defunctioned" jejunal loop (Fig. 5*e*, *f*) (*c*) Hepatico-duodenostomy (Fig 5*g*), alone, or combined with partial gastrectomy and posterior gastro-jejunostomy, as advised by Puestow (1953)
No extra-hepatic bile ducts can be demonstrated	[illegible] hepatico-duodenostomy or hepatico-jejunostomy
No extra-hepatic bile ducts can be found	Trace branches of hepatic artery to hilum of liver and core-out liver substance to locate intra-hepatic bile ducts, if unsuccessful, perform Longmire's operation of intra-hepatic cholangio-jejunostomy, employing a Roux-Y loop of jejunum (Fig 8)

THE TREATMENT OF INJURIES OF THE URETHRA

The treatment of injuries of the urethra is still a very controversial subject. Such injuries are relatively uncommon in civil life and few surgeons have had sufficient cases to allow comparison and evaluation of the different modes of treatment. Simpson-Smith (1936), reviewing the literature, found that all the available writings of the previous 20 years yielded some 381 cases. Of the 67 authors only 10 recorded a series of 10 or more cases and many of these series were collected and not a record of true personal experience. Silverstone (1942) continued the review, adding 10 more authors, 6 of whom recorded more than 10 cases. During the Second World War there was a tendency amongst British and American Forces to concentrate the traumatic and missile injuries of the urethra into special centres. As a result some extensive series of cases have been published and the experience gained has tended to establish more definite lines of procedure. Clarke and Leadbetter (1952) have compiled a bibliography and a review of reported experience. Gordon-Taylor (1950) has edited British Army experience. Progress in the treatment of shock and in the control of infection have also made possible earlier and more extensive primary repairs.

Sequelae of urethral injuries

Injuries of the urethra should not have a high mortality. When death occurs it is usually the result of severe concomitant injuries or of delayed treatment.

Stricture formation, urinary fistulae and chronic urinary infection are, however, all too frequently distressing sequelae. Boeckel (1898) wrote, "Toute rupture de l'urèthre est un rétrécissement en germe"; Morison (1916) stated, "Unless your skill can prevent the development of a stricture you are presiding at the opening of a life-long tragedy"; Morson (1941) claims, "I know of no case where the urethra has been completely torn across, in which the patient has been restored to perfect health."

Traumatic strictures may form extremely rapidly, thus differing from strictures of infective origin When the initial lesion is not severe the onset may be considerably delayed. The stricture may also be very [illegible] facts which may render dilatation diffi[illegible] and Marion (1914) have claimed that [illegible] shows little tendency to stricture formation. This view is, however, not generally accepted (Simpson-Smith, 1936). Many of the most difficult strictures occur in the prostato-membranous urethra.

The cause of stricture formation

Wounds of the urethra heal by the formation of scar tissue and it must, therefore, be accepted that after any urethral injury some degree of stricture formation is inevitable. Treatment must aim to reduce this fibrosis to a minimum. Careful treatment may achieve much; careless treatment may grossly increase the deformity. Success may only be claimed when the urethra remains of almost normal calibre, no fistulae are present and the urine is free from infection.

There are four main causes of stricture formation.

Inadequate approximation of the severed urethral ends

This leads to the formation of much scar tissue. Excisions for stricture of the urethra give the best results when the urethral ends are approximated accurately and without tension.

Sepsis at the site of the injury

Sepsis may ruin the most meticulous repair and cause gross scar formation. The

sepsis may be introduced by careless catheterization or the inadequate care of open perineal wounds. Urine flowing over the rupture and the presence of an in-dwelling catheter encourage the onset of infection and aggravate it when it occurs.

The severity of the primary injury

Considerable necrosis may occur in the lacerated urethral tissues giving rise to subsequent fibrosis. The very rapid stricture formation, which may even occur in some cases of incomplete rupture, may be explained on this ground. As long ago as 1906 Pasteau and Iselin pointed out the difficulty of determining the limits of tissue necrosis prior to carrying out an end-to-end suture. Kidd (1921) has written that it is "not the type of operation in the perineum, nor is it the tied-in catheter that are the real or chief causes of subsequent stricture but the pulping and lacerations of the corpus spongiosum. The severity of the stricture is determined by the violence of the blow and can be little influenced by the type of operation performed subsequently. The operator, who makes a careful estimate of the amount of damaged tissue and who removes this before suture, is likely to get the best results. Nevertheless, he can also improve his results by instituting bladder drainage, by refusing to employ the tied-in catheter, by leaving the repaired urethra entirely alone for 14 days after operation and then by inspecting the site of repair with the urethroscope before instituting treatment with dilators."

Damage by injudicious dilation

The healing urethra may be damaged by dilation carried out too frequently and with unnecessarily large bougies.

The principles of treatment

Largely owing to the pioneer work and observations of Guyon (1902), Rutherford (1904), Marion (1912), Heitz-Boyer (1909), Kidd (1921), Turner (1923), Simpson-Smith (1936), and others, the following general principles of treatment have been evolved.

(1) Urine must be diverted from the damaged urethra until healing is complete.

(2) The torn ends of the urethra must be brought into good apposition.

(3) The use of an in-dwelling urethral catheter must be avoided whenever possible during the process of healing.

(4) Sepsis must be avoided.

(5) Subsequent dilatation must not cause further damage to the urethra.

Classification

Injuries of the urethra may be classified as follows: (1) Ruptures. (*a*) Extra-pelvic (rupture of penile urethra, and rupture of bulbous urethra): (*b*) Intra-pelvic (rupture of posterior (membrano-prostatic) urethra) (2) External penetrating injuries. (3) Intra-urethral injuries.

Rupture of the urethra occurs when the urethra is damaged as the result of external trauma, but without the presence of an open wound. The rupture is said to be complete when the urethra is totally severed and incomplete when only a portion of the circumference is sectioned. The anterior urethra may be contused and the external fibrous sheath, cavernous tissue or mucous membrane damaged without a rupture occurring through the full thickness of the wall. French authors style these latter injuries respectively as partial external, interstitial and partial internal ruptures. The cavernous tissue is said to be the most easily damaged, then the mucous membrane, and lastly the fibrous sheath.

Penetrating *injuries* are rare in civil life, but may result from falls on sharp bodies, from road accidents (even a gear lever has been known to penetrate the rectum and injure the prostatic urethra), or from stabbing and gun-shot wounds. The varied missile injuries of war fall into this group. These urethral wounds are commonly complicated by severe injuries to surrounding structures.

The intra-urethral *injuries* may result from the passage of calculi or their removal. Foreign bodies introduced by erotics or inebriates and surgical instrumentation may also give rise to trauma.

RUPTURE OF PENILE URETHRA

Owing to the mobility of the penis its urethra is seldom damaged. It may occasionally be crushed against the pelvis or injured by acute flexion of the erect organ. The lesion is usually a contusion and even an incomplete rupture is very uncommon. Difficulty in micturition and extravasation are therefore very unusual. If urine has been passed, no special treatment, apart from urinary antiseptics, is required. In the event of retention a catheter should be passed, the bladder emptied and the catheter withdrawn. If the retention continues a small catheter may have to be tied in for a few days. Urethral bleeding may be marked but may usually be controlled by a cold compress. Occasionally severe haemorrhage may require compression of the penis by bandaging it firmly about a tied-in urethral catheter. In the rare event of a severe injury the urine must be diverted from the urethra by suprapubic cystostomy and a repair of the urethra performed.

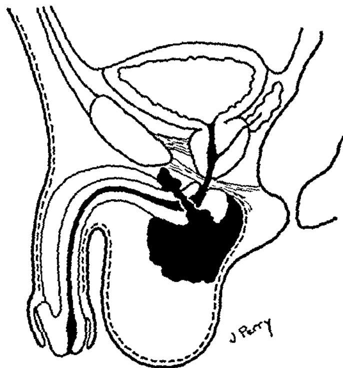


Fig. 9.—Complete rupture of the bulbous urethra showing haematoma formation beneath Colles' fascia.

RUPTURE OF THE BULBOUS URETHRA

Aetiology and morbid anatomy

The injury is caused by either a kick in the perineum or a fall astride a heavy object. The urethra is damaged by being crushed against the lower margin of the pubic arch or more rarely the bulb may be sheared off the lower surface of the pelvic diaphragm. The pelvis is rarely fractured. When the injury is due to crushing against the pubis, the lesion is placed more anteriorly than is usually described—about 1 inch

anterior to the point where the urethra perforates the pelvic diaphragm. The lesion may be a contusion, an incomplete or a complete rupture. When exposed at operation the divided ends of a complete rupture may appear retracted by as much as 1 inch. This retraction is largely due to the lithotomy position and the repair is made much easier if hyperflexion of the hips is avoided. The corpus spongiosum and urethral mucosa may show considerable laceration and bruising rendering it difficult to determine the limits of viable tissue (Fig. 9).

It is now rare to see extravasation following rupture of the bulbous urethra. Following a complete or incomplete lesion the internal and external vesical sphincters of the bladder go into spasm and the patient is quite unable to pass urine. It is only when the bladder, if unrelieved, finally overflows that extravasation occurs. Treatment has usually been sought long before this critical point is reached.

Diagnosis

In a typical case of rupture of the bulbous urethra there is a history of a perineal injury followed by severe localized pain. Bleeding occurs from the external meatus and a haematoma of varying degree forms in the perineum. The patient experiences an intense desire to micturate but is quite unable to do so. The retention is due to vesical sphincteric spasm and persists until the bladder finally overflows.

If following a perineal injury, severe enough to have caused meatal bleeding, a patient is able to pass urine and if there is no sign of a perineal haematoma or swelling, then it may be concluded that the urethra has been contused but that neither a complete nor an incomplete rupture is present. Surgical intervention is not necessary. The patient should be kept under observation and put on urinary antiseptics.

When retention is present in the absence of a perineo-scrotal haematoma, either a severe contusion or a small incomplete rupture is present. The patient is probably best treated as a case of incomplete rupture.

Treatment

Many operations have been practised for the repair of the ruptured bulbous urethra. They may be listed, approximately in their historical order of introduction, as follows.

Method 1. *Healing around an in-dwelling catheter.*—The rupture is exposed through a perineal incision as in external urethrotomy. The urethral ends are identified and an in-dwelling urethral catheter is placed in position. The urethra is left to reform itself around the catheter, whilst the perineal wound heals by secondary intention.

This operation was introduced by Cras and Guyon in 1876.

Method 2. *Suture of the urethra around an in-dwelling catheter.*—The rupture is exposed by a perineal incision The urethra is repaired by a partial or complete end-to-end anastomosis over an in-dwelling urethral catheter. The perineal wound may be partially closed or allowed to granulate.

Birkett (1866) inserted a single suture in the inferior wall of a ruptured urethra. The operation was revived by Guyon (1876) as a possible means of reducing stricture formation. It was subsequently adopted by most French urologists. The operation has received considerable support from English surgeons and was favoured by Hugh Young and other American surgeons.

Method 3 *The operation of Pasteau and Iselin.*—The ruptured urethra is exposed by a perineal incision No repair is attempted. The ends of the urethra are brought out and sutured to the skin in the mid-line of the perineum. The proximal urethral opening acts as a urethrostomy. At a later date the urethra is reconstructed by a plastic operation (Fig. 10).

In an effort to avoid the strictures resulting from the two previous operations Guyon (1902) suggested this operation The operation was first performed by Guyon

Penetrating injuries are rare in civil life, but may r
from road accidents (even a gear lever has been kno
injure the prostatic urethra), or from stabbing and
missile injuries of war fall into this group. These
complicated by severe injuries to surrounding structu
The intra-urethral injuries may result from the pas
Foreign bodies introduced by erotics or inebriates an
also give rise to trauma.

RUPTURE OF PENILE UR

Owing to the mobility of the penis its urethra is seld
ally be crushed against the pelvis or injured by acu
The lesion is usually a contusion and even an incompl
Difficulty in micturition and extravasation are theref
been passed, no special treatment, apart from urinary
event of retention a catheter should be passed, the bla
withdrawn. If the retention continues a small catheter m
days. Urethral bleeding may be marked but may usu
compress. Occasionally severe haemorrhage may requir
bandaging it firmly about a tied-in urethral catheter.
injury the urine must be diverted from the urethra
a repair of the urethra performed.

RUPTURE OF THE BULBOUS URETH

Aetiology and morbid anatomy

The injury is caused by either a kick in the perineum or a fall as
The urethra is damaged by being crushed against the lower
rch or more rarely the bulb may be sheared off the lower su
iaphragm. The pelvis is rarely fractured. When the injury is due
e pubis, the lesion is placed more anteriorly than is usually descri

Method 8. Marion and Heitz-Boyer's operation (1909) (Fig. 11).—Suprapubic cystostomy is performed. The ends of the damaged urethra are exposed in the perineum. They are freshened and mobilized if necessary. Complete end-to-end suture is performed over an in-dwelling catheter, which is then removed leaving no foreign body in the urethra. The perineum is closed around a small tissue drain.

Method 9. Marion's delayed operation.—At the time of the injury suprapubic drainage alone is performed. No attempt is made to repair the urethra. Any large perineal haematoma is drained. Six weeks later the urethra is repaired by Method 8. This operation was introduced by Marion in 1921. He had been impressed by the results of his excisions of strictures and believed that better results would be obtained with the ruptured urethra if the repair were carried out when the immediate effects of the trauma had subsided. Lepoutre and Stobbaerts supported this method.

Recommended procedure

Some satisfactory results have been claimed by all the above methods of repair and it is difficult to be dogmatic regarding procedure. In the author's experience the best results are obtained when the principles previously defined are adhered to as closely as possible. Amongst surgeons there is still too great a tendency to avoid diversion of the urine, to pay too little attention to the urethral repair and to leave an unnecessary in-dwelling catheter in position.

Immediate repair of the urethra is favoured. If, however, the patient's general condition is poor, if the surgeon is inexperienced in urethral repair or if the surgical facilities are inadequate for a meticulous operation, then the urine may be diverted from the urethra by suprapubic cystostomy and the repair carried out either in the course of the next day or two, or even in six to eight weeks when the perineal contusion will have subsided

The procedure of repair is as follows.

(1) Urethral catheterization to determine if the rupture is complete or incomplete.

(2) Suprapubic cystostomy to divert the urine from the urethra and if necessary to permit retrograde catheterization of the urethra.

(3) If the rupture is incomplete, perineal exploration is not required. The continuity of the urethra is present and it is unlikely that suture of the incomplete tear will improve on natural healing. If a severe stricture ensues a maximum of urethral tissue has been left for repair. A catheter is not left in the urethra. A large perineal haematoma may be evacuated.

(4) If the rupture appears to be complete the perineum is explored. The ends of the severed urethra are lightly trimmed and sutured over an in-lying catheter, which is removed when the repair is completed. If the urethral ends cannot be satisfactorily approximated they are aligned over a urethral catheter of small calibre, which is left in position.

(5) The perineum is closed around a small drain.

The technique of the operation

The operation is carried out with the patient in a modified Trendelenberg-lithotomy position, which is very similar to that used for synchronous combined excision of the rectum (Fig. 11) This position permits the abdomen, external genitalia and perineum to be cleaned and towelled in one step, and allows the carrying-out of the suprapubic and perineal stages of the operation without any change in position. A rubber pad is placed under the buttocks to raise the perineum from the table. The legs are held in position with guttered thigh and calf supports, which are mounted on ball and socket joints. It is important that the thighs should be fairly well abducted but only slightly flexed on the body. In this position the perineal tissues are relatively relaxed. Excessive flexion of the hips places the perineum under tension and causes wide separation of the tissues and difficulty in suturing.

The operation is commenced by passing a Tieman's catheter (10 or 12 Ch[illegible] gently into the urethra [illegible] the catheter is slightly [illegible] altered direction. If the [illegible]

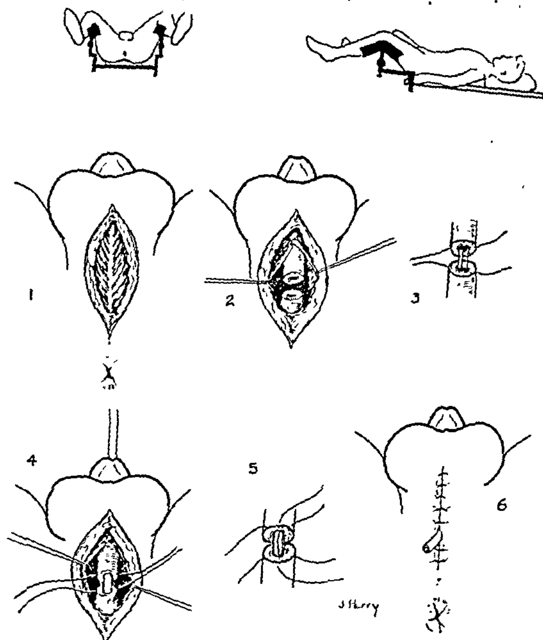


FIG 11.—The repair of a ruptured bulbous urethra. (1) The perineal incision; (2) the ends of the urethra have been exposed and trimmed, (3) the insertion of the sutures into the posterior wall; (4) the catheter has been introduced to steady the urethra during suture; (5) completion of suture; (6) the perineum is closed around a small drain. The catheter has been removed

the rupture is incomplete Continuity of the urethra is present and it is improbable that any useful purpose will be served by endeavouring to suture the incomplete tear. Perineal exploration is therefore not carried out. A large perineal haematoma may be drained. The catheter is then removed from the urethra. A suprapubic cystostomy is performed.

If catheterization is unsuccessful, either a complete or a severe incomplete rupture is present. The bladder is then exposed through a short suprapubic incision and a small opening made into it. The perineum is next incised in the mid-line (Fig. 11–1). If much

blood clot is present it is gently wiped away and an attempt made to identify the anatomical structures. The bulbo-cavernosus muscle is divided longitudinally and the urethra exposed (Fig. 11–2). A Clutton's sound passed up the anterior urethra may be used as a guide and, if gently advanced into the wound, will indicate the site of rupture and the distal opening of the urethra. A careful examination must then be made to determine whether the rupture is complete or incomplete and the degree of urethral damage.

If the rupture is incomplete a small Tieman's catheter is passed up the urethra and on into the bladder. The margins of the tear are examined, possibly trimmed, and then sutured over the inlying catheter with fine interrupted 3/0 plain catgut stitches. The sutures should pass through the mucosa and full thickness of the corpus spongiosum. If the margins are severely bruised and suturing difficult it may on occasion be advisable to make the rupture complete, to trim and mobilize the urethral ends and then to carry out a complete end-to-end suture.

When the rupture is complete the proximal end may be difficult to find, but can always be indicated by a bougie passed down the urethra from the bladder. The ends of the urethra having been found, they are gently trimmed and slightly mobilized so as to allow them to be brought together without tension. The posterior wall is united with two or three 3/0 plain catgut sutures (Fig. 11-3) A small catheter is then passed from the external meatus, across the rupture and on into the bladder It helps to steady the urethra during repair (Figs. 11-4 and 5). The suturing of the urethral margin is completed and if the repair is satisfactory the catheter is withdrawn.

If the damage to the urethra is severe it may be difficult to bring the ends together. By mobilization of the urethra it is possible to bridge gaps of 4 to 5 centimetres. In the presence of trauma the limits of mobility of tissues are uncertain and large incisions and wide mobilizations are better avoided. It is most important to avoid causing damage, which would render a good repair at a later date impossible In such cases the urethral ends should be aligned over a small in-dwelling catheter and any resulting stricture formation dealt with at a later date.

If it can be identified the bulbo-cavernosus muscle is then united over the urethra. A small rubber tube drain is placed in position and the perineal tissues brought together in layers with fine, plain catgut sutures (Fig 11–6). The skin margins are approximated with fine thread or nylon sutures The bladder is then closed around a Malecot catheter (26 Charrière). A drain is placed in the cave of Retzius and the abdominal wound closed.

If good results are to be obtained the importance of an unhurried operation, good anatomical exposure, the maintenance of as bloodless a field as possible, and the use of fine instruments cannot be over-stressed

After treatment

For the first few days the patient is kept almost flat and to minimize strain on the perineum the thighs are moved as little as possible Restlessness due to pain must be avoided. Oestrogens (10 mgms. of stilboestrol or dienoestrol eight-hourly) are given to control erections A mixture containing potassium bromide 15 grains, chloral hydrate 15 grains, and nepenthe 15 minims to the half ounce, is useful and, when given eight-hourly, helps to produce a state of drowsiness and to reduce penile turgidity.

Urinary antiseptics

Procaine penicillin (300,000 units) and streptomycin (1 gramme) are administered 12-hourly for the first week If there is any sign of urinary infection, the sensitivity of the organisms to the sulphonamides and other antibiotics is ascertained and the appropriate treatment given. The patient is kept on urinary antiseptics for at least six weeks.

Dressings

It is important to keep the whole of the genital and perineal region as sterile as possible. Too often a small pad is placed over the perineal wound and held in position by a flimsy T-bandage with the result that it comes adrift and the wound is exposed to infection. It is useful to cover the perineal dressings with a length of gamgee tissue, which extends like a baby's napkin posteriorly from the waist, down over the buttocks, and up over the perineum on to the abdominal wall. This is held in position by a binder with perineal straps.

Suprapubic drain

The Malecot catheter must be kept absolutely free so as to minimize the danger of urine passing down the urethra. If drainage is satisfactory, bladder lavage is avoided.

Cessation of suprapubic drainage

No definite time can be laid down for the removal of the suprapubic drain. Drainage is continued until the perineal wound is soundly healed. Normally in about 2 to 2½ weeks very gentle bouginage is carried out under pentothal anaesthesia. If the urethral channel is satisfactory, then in 2 or 3 days' time and when any irritation caused by the bouginage has subsided, a spigot is placed in the suprapubic catheter and the patient encouraged to pass urine through his urethra. If any leakage occurs from the perineal wound then suprapubic drainage is continued, but if after a few days the perineum remains absolutely dry then the suprapubic catheter is removed and the wound allowed to heal. Leakage from the suprapubic wound is usually slight as the track is oblique and the patient has already learnt to micturate. In-dwelling urethral catheters are not used to aid closure of the suprapubic wound, as it is unwise to risk starting even the mildest urethritis.

Dilatation of the urethra

The first examination of the urethra with bougies is carried out at about 2½ weeks from the operation. It is well to perform the examination under pentothal anaesthesia as the urethra may then be gently explored with the patient completely relaxed. The frequency of later examinations will depend on the degree of stricture formation. In a satisfactory case, instrumentation may be performed at intervals of 2, 4 and 8 weeks and finally at periods of 3, 6 or 12 months. The type and size of instruments passed will depend on the stricture, but over-dilatation must be avoided.

Late complications and their repair

Stricture and *fistula*, and the chronic urinary infection which may accompany them, are troublesome late complications. Stricture formation may be very pronounced. The formation of a fistula following repair or the persistence of infection may give rise to considerable periurethral fibrosis and local abscess formation. By [illegible]

temporary relief In the past, external urethrotomy has been [illegible] seldom gave a lasting result. In 1915 Russell described his treatment by incision of the stricture and reformation of the urethra from a riband of urethral wall. In France excision with end-to-end anastomosis was developed and repairs by the plastic operation of Pasteau and Iselin were practised. More recently, Swinney (1952) and Johanson (1953) have described their plastic methods of reconstruction.

Before deciding on a method of repair a full assessment of the stricture and any surrounding fibrosis, fistulae or abscess-formation must be made. A urethrogram will reveal the length of the stricture and may outline fistulae. If the stricture is localized, relatively uninfected and not surrounded by excessive fibrosis, then excision

with end-to-end anastomosis may be performed. Up to 4 or 5 centimetres of urethra have been excised, but it is well to keep below these limits. When the stricture is more extensive, and particularly if fistulae, gross fibrosis and sepsis are present, the reconstruction operations of Swinney and Johanson are preferable.

Excision of the stricture

The patient is placed in the modified Trendelenberg-lithotomy position. The bladder is opened suprapubically. A metal sound is passed down the anterior urethra to the stricture. The perineum is opened by a mid-line incision centred over the stricture. The urethra is exposed and divided transversely immediately distal to the stricture. The strictured urethra is then dissected proximally until normal urethra is reached. If any difficulty is experienced a metal sound passed in a retrograde manner from the bladder will act as a guide. The urethra is then divided proximal to the stricture The urethral ends are mobilized sufficiently to allow them to be brought together without tension. The suturing is carried out as described in the repair of the ruptured urethra. The perineal wound is completely closed around a small rubber drain. Suprapubic drainage is established.

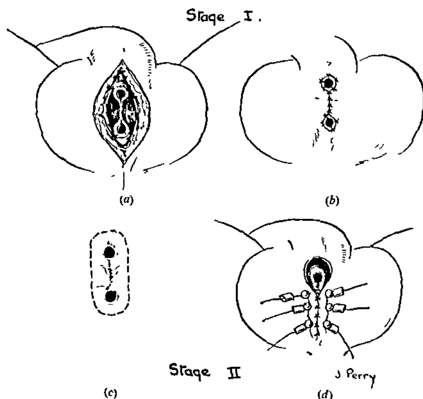


FIG 12—Reconstruction of the bulbous urethra by the Swinney and Johanson method Stage 1. (*a*) The stricture and fibrous tissue have been excised, (*b*) the peno-scrotal skin has been sutured around the margins of the urethral openings Stage 2. (*c* and *d*) The repair by the Denis Browne technique

Reconstruction of the urethra by the Swinney and Johanson operations

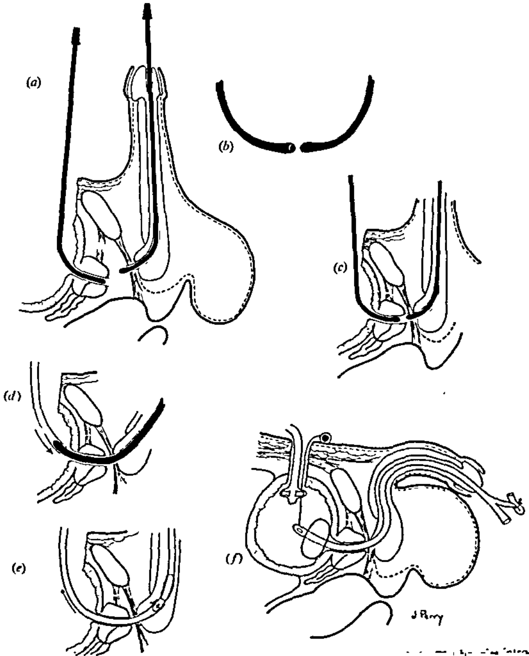
These operations are based on the pioneer work of Guyon, Pasteau and Iselin, but utilize the Denis Browne hypospadias technique for the plastic repair.

The operation is carried out in two stages.

First stage.—The urethra is exposed in the perineum by a mid-line incision. The urethral lumen is opened immediately distal to the stricture and is divided in the vesical direction until a lumen of normal calibre is reached (Fig. 12*a*). All surrounding

held the view that in the presence of shock it is inadvisable to undertake the difficult operation of immediate repair. The urine is diverted by an immediate suprapubic cystostomy. Six weeks later an attempt is made to reform the urethra.

In England and America it is felt highly desirable to re-establish the continuity of the completely divided posterior urethra as quickly as possible. With modern methods of resuscitation this can usually be done at the time of the initial operation. The repair should certainly not be delayed for more than a few days, as without alignment of the urethra the prostate may become fixed with dense fibrous tissue in an abnormal position, rendering effective repair at a later date almost impossible.



When the ruptured posterior urethra is approached by the suprapubic route it is difficult, if not impossible, to obtain a really accurate end-to-end suture. In the presence of a severe disruption of the pelvis there is also a considerable danger that pelvic movement may strain or break the suture line. For these reasons continuity of the urethra is usually maintained by introducing an in-dwelling catheter to act as a urethral splint (Bailey, 1928; Simpson-Smith, 1936; Poole-Wilson, 1947). Young (1926, 1928) and his followers have, however, advocated repair by the perineal route. More recently Hunt and Morgan (1942, 1949) have described a combined abdominal and perineal approach.

Along with the repair of the urethra it is important that there should be adequate reduction of the pelvic fracture so as to allow the damaged soft tissues of the pelvis floor to assume their normal position.

The technique of the suprapubic repair

The patient is prepared and placed in a flat position with the lower abdomen and genitalia exposed. A mid-line suprapubic incision is made. If there is any suspicion of an intraperitoneal lesion, the abdominal cavity is explored. The retropubic region is then exposed and will probably reveal a gross haematoma and possibly urinary extravasation. The free blood and any extravasated urine are cleared away. The presence of a fracture or dislocation in the pubic region is next determined and any loose fragments of bone are removed. The bladder and prostate are next examined. If a complete rupture of the posterior urethra is present the bladder may be found, often considerably distended and with its prostate attached, floating up on the top of a haematoma. In the event of the bladder and prostate continuing to occupy their normal position the possibility of an extraperitoneal rupture of the bladder is first excluded and a careful search is then made of the anterior surface of the prostate and its junction with the pelvic diaphragm for any evidence of an incomplete rupture of the urethra. A metal bougie passed up the anterior urethra to the point of obstruction will often reveal the urethral tear. The bladder is then opened.

The next step involves the restoration of continuity of the urethra by the introduction of an in-dwelling catheter. There are three possible methods.

(1) The two-bougie method. For this purpose it is an advantage to have a pair of Lister's bougies, the tip of one of which has been hollowed out, to form a cup in which the tip of the other may engage. This device was originally described by Banks (1927) and later used by Davis (1930) and others. Bowesman (1950) has devised a neat pair of interlocking forceps for this procedure.

In an apparently incomplete rupture the male bougie is passed up the anterior urethra until its tip reaches the point of obstruction. Viewing the anterior surface of the prostate may show the tip of the bougie held up at an incomplete rupture and a little manipulation under vision with a finger in the prostatic urethra may allow it to run on into the bladder. If difficulty is experienced then the female bougie is passed in a retrograde manner down the posterior urethra to the point of obstruction. By gentle manipulation the points of the two bougies are brought together and the male bougie then run through into the bladder. The distal end of a small Tieman's catheter (Charrière 16) is then slipped over the tip of the bougie, which it should grip snugly. By withdrawing the bougie the catheter is drawn into the urethra, where it is held in position as a urethral splint by a stitch passing through its tip and eventually tied over a rubber tube on the abdominal wall.

If the rupture is complete, the male bougie is passed up the anterior urethra and will appear in the pelvic floor. The female bougie is inserted from the bladder down the prostatic urethra (Fig. 14*a*). The bladder and prostate are then brought to their normal position, the tips of the bougies engaged and the male bougie run forward into the bladder (Fig. 14*c* and *d*). In these cases it is useful to use a Foley catheter with a 5 milli-

litre bag as a urethral splint so that gentle traction of 2–3 pounds may be used to keep the bladder and prostate drawn down into their normal position (Simpson-Smith, 1936). Unfortunately the side arm of a Foley catheter prevents it from being drawn into position in a retrograde manner. It is, therefore, necessary in the first place to draw a Tieman's catheter into position (Fig. 14*d*) and by attaching the tip of the Foley catheter to its distal end to draw it into position (Fig. 14*e*). In addition to distending the bag of the Foley catheter it is useful to hold it in position by a stitch through its tip, which is attached to a rubber tube on the abdominal wall. With this stitch in position it is possible at any time to draw a fresh catheter into position (Fig. 14*f*)

(2) The use of a catheter mounted on a metal introducer. A Foley or Tieman's catheter is mounted on an introducer and is passed up the anterior urethra until the point of obstruction is reached With a little manipulation it may be guided into the bladder. If the rupture is complete the posterior urethra may be threaded on to the catheter.

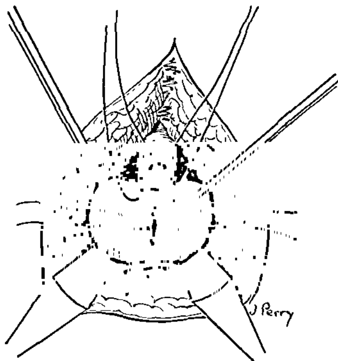


FIG 15 —Young's perineal approach for the repair of a ruptured posterior urethra.

(3) The two-catheter method. In cases of complete rupture Simpson-Smith passed one soft rubber catheter in a retrograde manner so that its tip appeared at the rent in the membranous urethra. An ascending catheter is then passed from the penis. The tips are joined by a stitch and the descending catheter is drawn through the urethra, or *vice versa*.

When the catheter is safely in position an attempt may be made to unite the divided urethra with a few sutures. The tissues are, however, usually grossly infiltrated with blood and no accurate suturing is possible. The bladder is then closed around a Malecot catheter, which acts as a suprapubic drain. The retropubic space is drained and the abdominal wall closed.

The treatment of the fractured pelvis must be planned in conjunction with an orthopaedic surgeon. Separation of the pelvis may be temporarily controlled with a tight binder. A counter-balanced pelvic sling, giving slight medial pressure, is frequently both useful and comfortable.

After treatment

The urethral catheter is left in position for at least two weeks. If the bony pelvis is then reasonably firm it is removed. A few days later the suprapubic catheter is

spigoted and the patient allowed to commence normal micturition. If this is satisfactory the suprapubic drain is removed and the wound allowed to close.

Dilatation is subsequently carried out, its periodicity depending on the results of treatment. In a good case it may be performed at intervals of 2, 4 and 6 weeks, subsequently increasing to periods of 3, 4, 6 and 12 months.

Despite the most careful treatment, considerable stricture-formation may occur. Gross periurethral fibrosis and distortion of the urethral tract due to incomplete reduction of the pelvis may give rise to difficulty in dilatation. In these cases chronic urinary infection and difficulty in micturition are prone to occur.

Other modes of treatment

The above operation has the objectionable feature of entailing an in-dwelling catheter. To most surgeons adequate suture of the torn urethra from the suprapubic approach has seemed impossible. The operation would be difficult in a normal subject but these difficulties are increased enormously when the pelvis is unstable from fractures, and the pelvic tissues contused and infiltrated with blood clot. Millin (1947) has suggested that "using a boomerang needle the prostatic apex would be approximated by three or more sutures to the distal urethra, avoiding the mucous membrane. The urethral catheter would then be withdrawn, a de Pezzer suprapubic tube placed in the bladder and the retropubic space drained routinely". So far this operation does not appear to have been put to the practical test.

Repair by the perineal route

It seems probable that actual suture of the completely ruptured posterior urethra is more easily carried out by the perineal approach Young (1926 and 1928) has performed and described his exposure by an inverted V perineal incision and division of the central tendon of the perineum. The haematoma above the triangular ligament is evacuated and the prostate, which has been carried upwards with the bladder, drawn down. A catheter is then passed from the external meatus down the anterior urethra out through the tear in the membranous urethra and through the prostatic urethra into the bladder. Around this catheter an anastomosis between the apex of the prostate and the membranous urethra is performed with interrupted sutures of plain catgut (Fig. 15). The catheter is left in to drain the bladder. The perineal wound is closed round a small gauze drain

Repair by a combined abdominal and perineal approach

In 1942 Hunt and Morgan described a repair carried out by a combined abdominal and perineal approach. The bladder was approached by the suprapubic route. The blood clot was cleared from the pelvic floor The bladder was then opened and a metal bougie was passed down the prostatic urethra At the same time a large soft rubber catheter was passed down the anterior urethra to the point of obstruction The

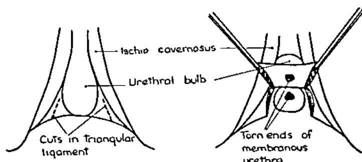


FIG 16—The repair of the ruptured posterior urethra by the abdominal and perineal approach of Hunt and Morgan

perineum was opened by a transverse incision just behind the urethral bulb, which was deepened to expose the tip of the soft rubber catheter and the bougie in the haematoma. The triangular ligament was then divided on each side by a cut extending from behind, forwards and inwards between the ischio-cavernosus and bulbo-cavernosus muscles (Fig. 16). The central part of the triangular ligament was left attached only anteriorly, hinged so that its upper abdominal surface could be brought into view. The bladder was then pressed down and an end-to-end anastomosis made between the torn ends of the urethra with 9 interrupted fine plain catgut sutures. When this was completed the penile catheter was removed. The bladder was drained with a de Pezzer catheter, a rubber tube was inserted in the cave of Retzius and the wound closed. In the perineum absolute haemostasis was secured and the divided structures loosely re-sutured. The incision was completely closed except for a small corrugated rubber tissue inserted into the subcutaneous layer. The patient made an excellent recovery. The suprapubic catheter was removed on the 15th day and the wound was dry in 3 weeks. Subsequent dilatation for 15 months showed no sign of stricture formation. Eight years later the patient was reported fit, leading an active life and requiring no dilatation. Sexual function was also quite normal.

In making the short cut into the triangular ligament there is a risk of dividing branches of the superficial nerve and artery and the nerve and artery to the bulb. In the case described no permanent damage was sustained.

This operation would seem to have great merit. As yet the author has no practical experience of its use.

Later complications

Occasionally alignment of the urethra may be lost during the course of treatment resulting in complete occlusion of the urethra It has been claimed that stricture formation is less prone to occur in the posterior than in the anterior urethra. In practice this is not so and is probably due to the greater difficulty in obtaining accurate apposition of the urethral ends. The extravasation of blood around the rupture, slight leakage of urine down the urethra and the presence of an in-dwelling catheter are also conducive to sepsis and stricture formation.

Repair of strictures

When the stricture is complete or is so tight or tortuous that micturition and dilatation are difficult three methods of repair are available.

Method 1.—The stricture is explored by a combined abdomino-perineal exploration. The bladder is first re-opened so that retrograde catheterization may be performed. The membranous and prostatic urethra are then exposed by Young's perineal approach. The ends of the urethra are sought, mobilization attempted and an end-to-end suture performed over a catheter, which is subsequently removed. The bladder is drained suprapubically during the period of healing.

This operation may be very successful. At times the urethral ends cannot be approximated and numerous attempts have been made to join the divided ends by strips of urethra. Few of these operations appear to have been truly successful.

Method 2.—Badenoch's pull-through operation. This operation was devised by Badenoch (1950) for strictures in the region of the membranous and prostatic urethra. The bladder is opened by the suprapubic route. The patient is then placed in the lithotomy position and a metal bougie is passed from the external meatus along the urethra to the stricture. The urethra is exposed by a mid-line perineal incision. It is divided just distal to the stricture. The bulbous urethra is then mobilized for 4-6 centimetres. A large metal bougie is passed suprapubically into the bladder and along the prostatic urethra as far as the stricture. The tip of the bougie can be felt in the perineum and with a scalpel an incision is made through the scar tissue of the stricture down to the bougie, which is then forced through to present on the perineum. This

artificial tract is dilated up to 30 Charrière size in an adult. A smaller bougie is passed and its tip firmly invaginated into the open end of a rubber catheter (Fig. 17), which is then drawn through from the perineum into the bladder. The tip of this catheter is inserted in the cut end of the mobilized urethra and threaded along it for a distance of 5–8 centimetres. The edges of the urethra are sutured with catgut to the catheter. By drawing on the catheter, the end of the bulbous urethra is pulled through the new channel in the uro-genital diaphragm and enters the prostatic urethra. The outer wall of the urethra may be stitched to the inferior layer of the uro-genital diaphragm, but the main means of fixation is by tension on the catheter, held in position by pressure

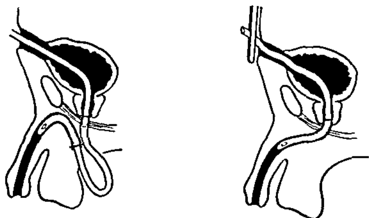


FIG. 17.—Badenoch's operation for the reconstruction of the prostato-membranous urethra.

forceps, which rest on the abdominal wall. The bladder is closed around a self-retaining suprapubic tube and the incision in the perineum is sutured in layers. About the 7th or 8th day the tension on the catheter loosens and it comes away. An instrument is passed on the 14th day, and if normal micturition has not been established a catheter is tied in the urethra. This is removed when the suprapubic wound has healed and instruments are passed at gradually increasing intervals.

Method 3.—Transplantation [illegible] cystostomy or transplantation of the ureters into the colon.

THE TREATMENT OF INJURIES OF THE BLADDER

Injuries of the bladder may be classified as follows.

(1) Ruptures (intraperitoneal, and extraperitoneal)
(2) Penetrating injuries.
(3) Surgical injuries.
(4) Injuries of the female bladder and urethra

Ruptures of the bladder

The rupture may occur on either the peritoneal or the extraperitoneal surface of the bladder. The intraperitoneal ruptures are due to a sudden rise of intravesical pressure bursting the bladder. They usually result from blows or falls on the abdomen, when the bladder is full and the abdominal muscles relaxed. The extraperitoneal ruptures affect the anterior or antero-lateral aspects of the bladder and follow severe trauma, which has fractured the pelvis. The tear may be caused by the fractured ends of bone penetrating the bladder or to the anterior surface being torn open by the pull of the lateral ligaments during the moment of disruption of the pelvis. A partial rupture of the posterior urethra may be accompanied by either an intraperitoneal or extraperitoneal vesical lesion.

The morbid anatomy, clinical features and means of diagnosis have been described in *British Surgical Practice* (Vol. 2, p. 114).

Treatment

The aim of treatment is to close the rupture in the bladder wall and to drain the bladder during the period of healing. A fracture of the pelvis is commonly present and every effort must, therefore, be made to avoid stagnation of urine and the introduction of infection lest a chronic osteomyelitis ensues.

The patient presents as a case of pelvic injury and there may be justifiable doubt as to whether an intraperitoneal or extraperitoneal rupture of the bladder is present or whether the posterior urethra is torn. A catheter is, therefore, passed. If it slips into the bladder easily and if a little blood-stained urine drains away a rupture of the bladder is probable. A suprapubic mid-line incision is then made. If an intraperitoneal lesion is suspected the abdominal cavity is opened.

Repair of intraperitoneal rupture.—The abdomen having been opened, free urine and blood are removed by suction. The abdominal viscera are examined and the wound in the bladder sought. The tear is usually small and is closed with an inner layer of No. 1 plain catgut sutures and an outer layer of No. 1 chromic catgut. When the wound is small and the repair satisfactory the peritoneum is completely closed and the bladder drained by an in-dwelling urethral catheter. The abdominal incision is closed. In the event of the bladder wound being large, the tear is repaired and the bladder drained suprapubically.

Repair of extraperitoneal rupture.—When an extraperitoneal rupture is present, urine and blood are found welling up from behind the pubis. The anterior bladder wall is sought for and may be found severely contused. If difficulty is found in locating the tear the bladder is opened between stay sutures and explored from within. The margins of the rupture are lightly trimmed and closed with two layers of sutures. If the repair is satisfactory the bladder is drained with an in-dwelling catheter and completely closed. The suprapubic wound is closed around a drain to the retropubic space. When the repair is difficult the bladder is closed around a Malecot catheter used as a suprapubic drain. After a week, if progress is satisfactory, the suprapubic drain is removed and the bladder drained by an in-dwelling catheter until healing is complete.

Penetrating injuries

As in the case of the urethra penetrating injuries are rare in civil life, but not uncommon in war (Culp, 1947; Kimbrough, 1947; Mogg, 1947; Poole-Wilson, 1950; Robinson and others, 1946). The perforation of the bladder is only one incident in a pelvic wound and the missile may also have penetrated the peritoneal cavity, perforated the rectum or shattered portions of the pelvis. The degree of damage is very variable. A bullet may traverse the bladder leaving only a minute entry and exit wound, whilst a fragment of shell or bomb may tear a large opening and destroy much bladder wall.

Treatment

Operative treatment entails toilet and examination of the superficial wounds. A mid-line suprapubic incision is then made and the peritoneal cavity explored. When the rectum is injured a left iliac colostomy is established. The bladder is next examined and foreign bodies and loose fragments of pelvic bone are removed. When possible the vesical wounds are excised and sutured. A suprapubic cystostomy is then established and the cave of Retzius drained. Under ideal conditions many perforations of the bladder might be treated by immediate closure and drainage through an in-dwelling urethral catheter. In times of war meticulous after-care is often lacking and

evacuation may be necessary. Under such conditions an in-dwelling urethral catheter is quite unsuitable and suprapubic drainage is essential.

Wounds of the vault and anterior wall of the bladder are usually easily closed. Large wounds low down on the lateral walls present a serious problem. Shattering of the pubic rami and accompanying contusion of the tissues can make the identification of the limits of the wound extremely difficult. The base of the bladder is also relatively fixed and great difficulty may be experienced in trying to close the wounds. Too often the suture line, which has been under tension, breaks down and infected urine drains into the fractured pelvis causing chronic osteomyelitis. The margins of the vesical wound become adherent to the pelvic wall and a permanent fistula is established. To avoid such troubles every effort must be made to close the bladder around a suprapubic drainage tube and to aspirate the urine continuously with a Stedman electric suction pump.

It is usually impossible to suture wounds of the base of the bladder satisfactorily and more harm than good may be done by attempting to do so. Nature effects much repair in this area and it is well recognized that traumatic recto-vesical fistulae very frequently close spontaneously.

Surgical injuries of the bladder

During open operations

The bladder may occasionally be injured during the repair of a hernia or during a gynaecological operation.

Trans-urethral injuries

Aetiology.—Any periurethral instrumentation of the bladder carries with it some danger of vesical perforation and extravasation. With ordinary care the accident is unlikely to occur during cystoscopy unless the bladder wall is seriously weakened by disease. Thus in the course of examining a contracted tuberculous bladder an instrument may occasionally run through the bladder wall into the peritoneal cavity.

Perforation is, however, more prone to occur during the transurethral treatment of intravesical lesions. Too deep a cut may be made during the course of a periurethral resection of the prostate or too deep a bite during biopsy or removal of a vesical tumour The bladder wall may also be crushed during litholapaxy or burnt too deeply during diathermy. Over-distension may also cause a rupture Such a disaster is most prone to occur in the treatment of interstitial cystitis by over-distension or by the use of an evacuator following litholapaxy when the bladder wall has been contused. The lesion may be intraperitoneal or extraperitoneal The type of procedure being performed usually gives a fair indication of the site of the perforation.

Symptoms.—When under spinal or local anaesthesia the patient complains of the sudden onset of abdominal pain This may be accompanied by a fall in blood pressure and a deterioration in the patient's general well-being. The operator may also notice an inadequate return of fluid from the bladder, which may be accompanied by an unexpected degree of haemorrhage. When a cystoscope has been passed through the bladder, coils of intestine may occasionally be recognized. In the bladder the site of the perforation may be seen through the resectoscope or cystoscope.

Treatment.—The ultimate course of an operative perforation of the bladder may be extremely serious. Much fluid may have been extravasated under pressure from the bladder into the peritoneal cavity or perivesical tissues. In addition infection may have been present in the bladder due to the primary lesion. A gross septic extravasation may therefore be present. When the perforation has taken place in the course of a periurethral resection of the prostate, the periprostatic plexus of veins may also have been opened. Fluid may have been forced into the venous system and, unless an isotonic irrigating solution has been used, may cause haemolysis and anuria. Some of the

deaths, attributed in the past to anuria arising from an accompanying *pyelonephritis* or a transfusion reaction, may be explained on this ground.

If the diagnosis of perforation is in very real doubt and provided the bladder urine is uninfected it is justifiable to insert an in-dwelling Foley catheter, to place the patient on a full protective course of antibiotic drugs and to keep him under very close observation. A retrograde cystogram may at times help in the diagnosis, but the filling of the bladder should be limited. There is no doubt that a small perforation may heal under such treatment, but the course is inclined to be precarious. If any deterioration in the patient's condition occurs a full suprapubic exploration must be carried out.

When the diagnosis of perforation is probable, and certainly in the presence of a septic bladder, immediate suprapubic exploration must be carried out. The site of the lesion under treatment will probably have given a guide as to the probability of intraperitoneal or extraperitoneal perforation. If there is any doubt it is wise to explore the peritoneal cavity. If the perforation has been in the region of the bladder neck there will probably be considerable extravasation and haemorrhage in the retropubic region. The bladder is then opened. If possible the perforation is closed with sutures, but in the region of the bladder neck this may be difficult. The bladder is finally closed around a Malecot catheter and a drain is placed in the cave of Retzius.

In the past the mortality of these lesions has been high. Culp (1942) reported a series of 33 ruptures of the bladder, all except 2 of which were due to surgical procedures, with a mortality of 64 per cent. Most of the cases were treated in the pre-sulphonamide days; amongst 8 cases treated with these drugs the mortality fell to 37·5 per cent. The introduction of the antibiotics and the insistence on early operation has almost certainly effected an improvement.

Injuries of the female bladder and urethra

Aetiology

Injuries to the female bladder and urethra may be classified into three groups.

(1) Injuries occurring during child-birth.

(2) Injuries resulting from trauma or surgery.

(3) *Injuries following radiation therapy.*

Injuries due to difficult labour are becoming more rare in most countries. In lands where contracted pelvis is common and maternity services poorly developed *many cases still occur.* Mahfouz of Cairo has reported a very large series. Traumatic injuries may result from the unskilled passage of catheters, the use of pessaries, sexual perversions and rape. More commonly they are the result of surgical operations. A high proportion are caused by difficult gynaecological pelvic operations, but a fair [illegible]

formation, sepsis and necrosis of the bladder wall. The sling [illegible] control of incontinence have also caused such injuries. Radiation injuries usually occur long after treatment has been completed and are the result of devascularization of the tissues.

Treatment of recent injuries

When the bladder or urethra is injured during child-birth or in the course of a vaginal operation, repair is by choice carried out immediately. In deep pelvic operations, however, the injury may not be recognized at once and only become obvious when urinary incontinence indicates the presence of a vesico-vaginal or uretero-vaginal fistula.

[illegible] No. 1 plain catgut [illegible]

amounts of vaginal wall as in the event of a [illegible]

tissue as possible available for repair. An in-dwelling urethral catheter is placed in position to drain the bladder. The catheter may be removed in 7–10 days, at the end of which time, healing in the majority of cases will have occurred.

Vesico-vaginal fistula

Injury to the bladder or urethra may not have been recognized and incontinence of urine may be the first indication of trouble. Inspection and vaginoscopy may reveal the site of the urinary leakage, but small fistulae may be easily overlooked. In difficult cases a vaginal swab examination may help. A catheter is first passed and the bladder emptied of urine. The vagina is then dried and lightly packed with ribbon gauze. About 2 ounces of a 4 per cent indigo carmine solution are then introduced into the bladder through the catheter, which is then withdrawn A pad is applied to the urethra and the patient allowed to move about for an hour or two. The pad is then removed and the gauze is withdrawn. If the gauze remains unstained and dry it is unlikely that a ureteric or vesical fistula is present. If wet with clear urine a ureteric fistula is present. Staining with dye indicates a vesico-vaginal fistula If the vaginal pad only is soiled then the leakage is due to urethral incontinence.

Intravenous pyelography and cystoscopy will help to clarify the diagnosis.

As a result of these examinations the exact degree of damage should be ascertained and will be found to vary from small fistulae to large gaps in the posterior bladder wall, which may run down into the urethra. Multiple fistulae are not uncommon. It is essential to determine the position of the ureteric orifices in relation to the fistula and also whether the neck of the bladder with its sphincteric mechanism has been destroyed.

Spontaneous closure of vesico-vaginal fistulae, even when assisted by continuous bladder drainage, is very uncommon Relief of the condition is usually attempted by one of the following methods

(1) Repair of the fistula by the suprapubic route.

(2) Repair by the vaginal route.

(3) Partial colpocleisis.

(4) Diversion of the urine to the sigmoid colon by ureteric transplantation.

Repair by the suprapubic route.—Amongst general surgeons and urologists there is a tendency to use this approach. The fistula can be reached either transvesically or extravesically by separating the peritoneum from the posterior wall of the bladder, or transperitonally. In some instances the bladder may be opened suprapubically, separated from the peritoneum and then split down the mid-posterior line into the fistula. Whichever approach is used the closure of the fistula is usually troublesome owing to the depth of the affected area and difficulty in mobilizing the base of the bladder and freshening the edges of the fistula. Too often an inadequate repair is obtained and the fistula remains.

Repair by the vaginal route.—In the literature the most successful series of cases have been carried out by this route. It is claimed that resort to the suprapubic route is neither necessary nor helpful (Mahfouz, 1938; Moir, 1954, Russell, 1951).

There are two methods of carrying out the vaginal repair.

(1) *Vaginal closure in layers.*—The bladder and vagina are widely separated from each other around the fistula. This procedure may be assisted by starting the separation about 0 5 centimetres from the fistula margin. The bladder is then sutured with interrupted plain (No. 1) catgut sutures and the vagina closed in a separate layer over it.

This operation is suitable for patients with plenty of healthy tissue surrounding the fistula, but becomes impossible in gross fistula and especially if there is much scarring from previous operations

(2) *Closure in one layer—The Sims-Emmet operation.*—This operation, although

the least shocking to the patient and the most easy to perform, when properly carried out has given excellent results (Moir, 1954; Russell, 1951). In the writer's more limited experience it is the operation of choice.

The writer commences the operation by introducing a cystoscope and passing a catheter up each ureter. Provided an irrigating instrument is used this manoeuvre may be performed even though the fistula be a large one. The catheters are left in position and serve as useful guides to the position of the ureteric orifices and ureters.

The operation may be performed in either the lithotomy or knee-chest position. The essential feature of the operation is to produce a broad raw surface around the fistula consisting of adherent bladder and vaginal walls, which will then be drawn into apposition by sutures. The fistula is first drawn down into view with tissue forceps. The incision starts about 0·75 to 1 centimetre from the fistula margin and divides the tissues obliquely down to the bladder at the fistula margin. The incision is continued round the fistula giving a raw surface at least 0·5 centimetres wide. Moir describes this procedure as saucerization (Fig. 18). The raw margins of the

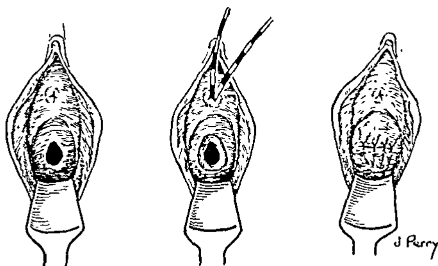


FIG. 18.—The Sims-Emmet operation for the repair of vesico-vaginal fistula.

fistula are then drawn together in the most suitable direction by interrupted sutures of silver wire (No. 32 gauge) or nylon (No. 5), which preferably pass down to, but not through, the bladder mucosa. Any tension may be eased by relieving incisions in the vaginal wall. The silver wire sutures are extremely useful as they may be tightened by gentle twisting to give just the right degree of tension.

At the end of the operation the ureteric catheters are withdrawn and a small indwelling Foley or Malecot catheter is inserted through the urethra into the bladder. If the repair has involved the neck of the bladder it may be wise to drain the bladder by the suprapubic route, but in most instances this is not necessary.

The patient is allowed up on the 7th day. Urethral drainage is continued for 7–10 days. The silver stitches are removed on the 21st day.

[illegible] of the vagina [illegible] hen the [illegible] obliteration of the vault has been almost [illegible] pouch from the bladder has remained results appear to have been satisfactory. The writer has never personally performed this operation, but has looked after two such patients in whom a large pouch remained and who suffered much from chronic cystitis and stone formation. Finally ureteric transplantation was carried out in each case.

Ureteric transplantation.—Most vesico-vaginal fistulae resulting from trauma may be repaired. When a gross injury involves the bladder neck and urethra it may be

possible to close the vesical gap and reconstruct the urethra, but frequently it is impossible to restore the function of the vesical sphincters. Sling operations rarely give much relief to this type of incontinence and the condition is best relieved by transplanting the ureters into the sigmoid colon. Many methods of transplantation are available. In the writers' hands the Leadbetter technique (1951) has been the most successful.

Ureteric transplantation may also be required to relieve patients suffering from post-radiation fistulae. In these patients scarring and avascularity of the tissues may render repair impossible.

(*See also British Surgical Practice*. Bladder Injuries, Vol. 2, p 114, S. Key 55)

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BONE AND JOINT TUBERCULOSIS: THE VALUE OF ANTIBIOTICS

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It is now 7 years since antibiotics have been available for the treatment of tuberculosis. In the first 2 years streptomycin was commonly used alone. In the next 3 years, results with PAS and combinations of streptomycin and PAS were published and in the last 2 years *iso*-nicotinic acid hydrazide and its isopropyl derivative have been available for use alone or in combination with the earlier drugs. These are the only anti-tuberculous drugs which have been found valuable in orthopaedic tuberculosis.

Even when antibiotics are used, tuberculosis of bones and joints is a condition of slow development and of slow response. Seven years is not a long time in which to assess the value of a new treatment, especially when further possibilities have become available during that period of time.

It is proposed to consider the results so far obtained under three headings.

(1) Evidence that antibiotics have a real effect upon these conditions.

(2) The value of antibiotics as enabling agents; that is to say, evidence that they render possible other treatments previously found too dangerous or ineffective.

(3) Basic facts about chemotherapy to be taken into account by orthopaedic surgeons as well as by anyone else requiring to use these drugs.

ASSESSMENT OF ANTIBIOTIC TREATMENT OF BONE AND JOINT TUBERCULOSIS

Diagnosis

Certain ground must be cleared by way of definition. It is of the utmost importance when assessing results in this field that diagnosis should as far as possible be beyond doubt. It may be objected that this is obvious. The writer, however, would assert that although it is essential it is by no means obvious. Many series have been published in which diagnoses have been made largely on a basis of clinical and radiological impressions. In a large hospital where orthopaedic tuberculosis has been observed over the last 8 years, and where every attempt has been made to prove the diagnosis when tuberculosis was suspected, it has been a source of surprise how important this matter of proof can be. Many patients have been seen who were thought to be tuberculous upon clinical and radiological grounds, and even upon naked eye appearances of the lesion at operation, but who eventually proved not to be so.

Mantoux tests should always be positive at least at 1/100 dilution; with active tuberculosis it is usually positive at 1/1,000 or commonly at 1/10,000 The assertion [illegible] Mantoux reaction at 1/100 dilution rules out a diagnosis of tuberculosis [illegible]

and such material should be given to the [illegible]logist for Loewenstein culture and guinea-pig inoculation. It is true, of course, that even with all these tests the occasional case of tuberculosis will elude diagnosis for

a time. At least two tuberculous knees have been seen which reached their third synovial biopsy before positive results were obtained. However, the previous material had only been examined histologically and the inclusion of every possible test on all material obtained should diminish the number of false negatives. But here we are concerned only with the positive results, that is conclusions about the efficacy of chemotherapy upon series of proved cases. With regard to spinal disease, of course, we are in greater difficulties. Where there is an abscess to be aspirated or where operative treatment is undertaken it may be possible to obtain material for bacteriological and perhaps also histological examination. Ordinarily, however, it is true that the diagnosis of Pott's disease will have to be accepted on the basis of positive Mantoux and the clinical and radiological findings. In any large series so diagnosed it is inevitable that a few will eventually prove to be chronic staphylococcal, *B. abortus* or other infection, and such cases must be rigorously weeded out as the series is followed.

TABLE I

TUBERCULOSIS OF HIP-JOINT: RETURN OF TRABECULATION AND CORTICAL OUTLINE WITH AND WITHOUT STREPTOMYCIN TREATMENT

	Months	*Average months*
Pre-streptomycin hips 40 *cases*		
Length of history before treatment	1–24	8
Conservative treatment before recalcification	8–28	15
Streptomycin hips 18 *cases*		
Length of history before treatment	1–42	8
Conservative treatment before recalcification	3–14	7

Time factor in assessing results

The second point is the necessity for adequate time for the assessment of results. Inclusion of any case in a published series should imply time for diagnosis and for adequate treatment and then 2 or preferably 3 years for observation after return to normal life. This means, for each case, a total of something between 3 and 5 years. Lastly, in the assessment of results we must necessarily work from that which we know to that which we are trying to find out with the minimum of new factors introduced; in other words, as far as possible the antibiotic the efficacy of which is being tested must be superimposed upon previously used methods whose efficacy is known or can be assessed from hospital records.

The papers published up to 1950 were, as might be expected, in the main somewhat extravagant in their claims with inadequate follow up of the patients treated (Review of Bone Tuberculosis and Streptomycin, 1949; Huwyler, 1950, Bickel, 1949; Tucker, 1949, Parisel and De Doncker, 1950; Seree and Dettloff, 1950). Generally, upon both sides of the Atlantic, it was said that streptomycin was beneficial for sinuses, that it enabled certain operations to be performed which otherwise were not safe, but that its evaluation for closed bone and joint lesions was difficult In fact, it has not been easy to find comparable series of patients with closed bone and joint lesions treated conservatively with and without streptomycin

Case studies

To show the effect of streptomycin upon such cases quotation has been permitted from *The Journal of Bone and Joint Surgery*, February 1954, of [illegible]

disease in the knee, in children. A further series with sinuses given intra-muscular streptomycin is used to illustrate the results in that type of case, a fourth group with

synovial tuberculosis of the knee in young adults were given intramuscular and intra-articular streptomycin and oral PAS in a special régime to be detailed later. Another group similar to this last was published by Smith and Bailey (1953).

First series

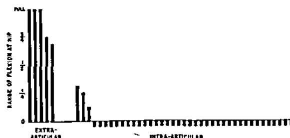
In the first series intramuscular streptomycin was used for closed bone and joint lesions at the hip.

This series is chosen because, having been started in 1948, the patients have been adequately followed since treatment. The diagnoses were all proved and the patients treated for their initial disease, all relapse cases being excluded. They received the ordinary conservative treatment that had for many years been used in the hospital without any surgical intervention except for necessary gland biopsies. Streptomycin was given for 3 months in a daily dosage of ½ gramme for ages up to 5 years, ¾ gramme for ages 5–10 and 1 gramme for 10 years and upwards. The 18 cases were compared

TABLE II

TREATMENT OF TUBERCULOUS HIPS BY STREPTOMYCIN (INTRAMUSCULAR) AND CONSERVATIVE TREATMENT
STANDARD THREE-MONTH COURSE

Patient	*Age at onset*	*Symptoms before conservative treatment in months*	*Total conservative treatment in months*	*Conservative treatment after strep in months*	*Conservative treatment before first signs of recalcification in months*	*Mobility*	*Follow-up after strep. in months*
Intra-articular							
1	12	12	5	0	6	Nil	53
2	12	12	14	9	12	Full	34
3	2½	18	12	9	8	Flex Full Abd 45° Rot. Full	42
4	8	30	15	6	14	Flex. 135° Abd. 35° Add. 30° Rot. 15 & 15	43
5	13	7	16	12	6	Flex. Full Add Full Abd. Full I.R. Nil E.R. 15°	50
6	9	24	6	3	6	15–80°	28 Relapsed 1 yr. after strep.
7	3½	1	15	9	8	Nil	48
8	4½	8	10	5	5	Nil	44
9	3	1	16	9	10	Nil	44
10	9	9	12	9	4	Nil	34
11	22	42	18	14	14	Nil	48
12	2½	24	18	13	5	Nil	60
13	6	2	13	9	3	Flex. 10–85° Abd. 0–30° Add. 0–10° I R. Nil E R. Slight	35
14	25	1 week	9	4	4	Nil	47
15	4½	2	10	6	3	Full	22
Extra-articular							
16	10½	4	11	7	7	Almost full	30
17	1½	1	6	2	6 11	Full both hips	44
18	3	5	4	0	5	Full	44



(By courtesy of the Journal of Bone and Joint Surgery).

with 40 extracted from the records of the hospital who received the same conservative treatment and who had had the same range of lengths of history before diagnosis and treatment. Comparison was made upon two objective points chosen to free the results claimed from the uncertainty of clinical impressions. These two points were firstly, the rapidity with which improvement could be observed radiologically, that is to say, how long it was after the beginning of treatment before the three-monthly radiographs of the lesion showed beginning return of both trabeculation and cortical outline, the first radiological evidences of healing; the second point was the degree of ultimate mobility obtained Table I shows the results with regard to the first point. The length of time before the onset of recalcification had been reduced to half. The mobility results are even more striking and are shown in Figs. 19 and 20. The full details of the patients in this series were as shown in Table II.

It was also found that the surgeons in charge of the patients who had continued to treat upon ordinary principles, that is, clinical and radiological observation before decision to remobilize, and who had deliberately ignored the added streptomycin, had, in fact, found it possible to reduce the length of conservative treatment very considerably. This is shown in Table III where comparison is made with previous records in the same hospital

TABLE III

DURATION OF CONSERVATIVE TREATMENT

		Average
Pre-streptomycin hips	*50 cases*	
Extra-articular		21 months
Intra-articular		24 months
Stretomycin hips	*18 cases*	
Extra-articular		8 months
Intra-articular		13 months

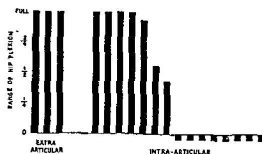
Second series

In the second series 7 cases of tuberculosis of the knee in children, 6 of them synovial, were treated with splinting of the joint and intramuscular streptomycin. The mobility results are given in Fig 21.

These patients have been followed for the lengths of time shown in the table of details (Table IV) and these extremely good results were obtained despite the fact that the average length of immobilization was only 7 months

There have been no relapses among the knees. Subsequent relapses occurred in 3 cases of hip disease, but not in any of those in whom good mobility had been obtained. All 3 were patients whose immobilization had been continued for less than 6 months after the end of the streptomycin course; it is obvious that there is a limit below which it is still unsafe to reduce the period of conservative treatment. This, however, may be improved upon with the additional use of PAS and *iso*-nicotinic acid hydrazide. It will be remembered that the series in question received only streptomycin for no longer than 3 months.

Smith and Bailey (1953) have published 5 cases of synovial tuberculosis of the knee joint in young adults treated by intramuscular streptomycin for 3–4 months with immobilization for periods varying between 4 months and 2 years. These cases have been followed up for from 2–5 years before publication. Four have now normal knees radiologically and clinically with mobility ranges of 90°, full movement, full



[illegible] months). Number of patients 18 (3 extra-articular, 15 intra-articular)

(*By courtesy of the Journal of Bone and Joint Surgery*)

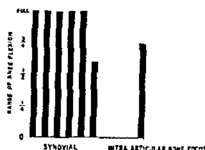


FIG 21.—Mobility results in tuberculosis of the knee-joint. Conservative treatment with streptomycin Range of follow-up after streptomycin 26 to 54 months (average 42 months) Number of patients 7 (6 synovial; 1 with intra-articular bone focus).

(*By courtesy of the Journal of Bone and Joint Surgery*).

movement and 125°. The fifth case was arthrodesed because it was expected that such routine treatment would be necessary. In fact, operation findings failed to show any effusion, pannus or subchondral foci, and the synovium was normal to the naked eye.

TABLE IV

TREATMENT OF TUBERCULOUS KNEES BY STREPTOMYCIN (INTRAMUSCULAR) AND CONSERVATIVE TREATMENT STANDARD THREE-MONTH COURSE

Patient	*Age at onset*	*Symptoms before conservative treatment in months*	*Total conservative treatment in months*	*Conservative treatment after strep. in months*	*Mobility*	*Follow-up after strep. in months*
Knee with bone destruction of a femoral condyle by intra-articular focus						
19	3½	3	12	4	30°–Full	45
Knee joint with synovial tuberculosis						
20	1½	2	8	3	Full	54
21	1¾	10	4	0	Full	46
22	6	24	4	0	Full	49
23	17	3	5	1	0–90°	42
24	2½	10	4	1	Full	32
25	2¾	6	10	5	Full	26

The views of Girdlestone and Somerville in their standard work, *Tuberculosis of Bone and Joint*, 1952 edition may be summarized as follows.

(1) Synovial disease in young children may give a good result with considerable range of mobility after very prolonged conservative treatment. In the cases they [illegible] the average complete plaster spica immobilization was 16 months and the [illegible] immobilization of the series in Table IV.

(2) Excision of the joint is the standard practice for patients with confirmed tuberculosis of the knee aged 15–50.

Johannes Mortens (1948) in his book *Tuberculosis of the Knee Joint* under the heading "Synovial Tuberculosis in Children" also speaks of the duration of the disease being expected to continue for anything up to 4½ years under conservative treatment.

Further observation is obviously necessary, but it would at least seem likely that both these statements may be due for revision.

Third series

This series included 4 cases of chronic synovial tuberculosis of the knee joint in young adults who still retained a very large range of movement. Synovectomy upon 2 similar cases under chemotherapy cover had resulted in the loss of more than half of their range of movement. It was, therefore, decided to treat these 4 by streptomycin intramuscularly, PAS orally, with *bed rest but no splinting*. Streptomycin, 1 gramme, was also given intra-articularly once or twice a week. The results were excellent as regards mobility and fuller details with length of follow up are given in Table V.

TABLE V

SYNOVIAL DISEASE OF THE KNEE IN ADULTS

Patient and age at treatment		*Sex*	*Length of history before treatment*	*Mobility before treatment*	*Time without weight-bearing*	*Mobility end of 1953*	*Clinical state of knee*	*Time since course in months*
26	24	M	5 years	10–110°	4 months	5–120°	No synov thickening. No effusion, heat or spasm	36
27	20	F	6 years	0–110°	5 months	0–120°	Normal	32
28	20	M	15 months	10–100°	7 months	0–135°	Normal	16
29	35	F	3 months	0–80°	5 months	Full	Normal	13

All had [illegible]

Very similar methods and dosages, intramuscular and intra-articular, were also used by Hald (1953) He obtained full knee flexion for 10 out of 13 patients followed for an average of 2 years. Both myself (1954) and Fellander (1953) showed that synovial fluid would contain good therapeutic levels of streptomycin after intramuscular injection and very much higher levels for several days after intra-articular injection.

Fourth series

A review of the literature of the last 7 years clearly shows that patients with sinuses were at first considered only from the point of view of treatment of their sinuses. More recently, however, consideration has been given to the treatment of the underlying cause of the sinus. That aspect will be discussed later. From 1948 onwards this series was collected at the Royal National Orthopaedic Hospital and treated conservatively as the lesion demanded, with the superimposition of 1 gramme of streptomycin intramuscularly daily for 3 months. Sinuses, of course, do heal in many cases without antibiotics as is shown in the following figures from the hospital records of 20 patients with 26 sinuses from the days before chemotherapy.

Healing time	*No. of sinuses*
Less than 4 months	4
4-6 months . .	5
7-9 months . .	6
10-12 months .	7
13-18 months .	2
5 years . .	1
7 years . .	1

The criteria for healing as a result of the streptomycin were, therefore, made severe; that is to say, that the healing should have occurred during the 3 months course and that the sinus should not have broken down for at least 2 years afterwards. As a fact, the 28 patients in the chemotherapy series have been followed now for between 3 and 4 years. They included 18 from the spine, 3 from the greater trochanter, 1 from the os pubis, 2 from the knee, 2 from the hip, and 2 skin tuberculomas with an orthopaedic lesion. The success rate by the criteria as defined was 61 per cent. Great improvement without complete healing was obtained in a further 14 per cent. These are much the same figures as have been obtained in a number of other mixed series. It is, however, pertinent to note that on re-examination of the failures it was observed that their radiographs in every case but one showed adequate reason for non-healing in the presence of sequestra, large calcified masses or bony bridges preventing the vertebrae coming together and fusing Such evidence was absent in the patients whose sinuses healed.

A more radical approach to sinuses was first indicated by two important papers: Arico, Cincotti and Harken (1948), and Boone, Cincotti, Kelley and Salzberg (1949). Both these groups published series of cases in which, under streptomycin cover alone, they had radically opened up the sinuses, removed as much as possible of the diseased tissue, packed with iodoform gauze and irrigated with azochloramide for 7–10 days, following with a secondary suture. One paper claimed rapid healing in 100 per cent and the second in 90 per cent.

It has been shown that intermediate figures for healing can be obtained by the use in chosen cases of streptomycin injected up the sinus (Ahern, 1950). He obtained success in 80 per cent of 49 cases.

It would appear then that streptomycin alone will alter the natural history of treated orthopaedic tuberculosis in a recognizable way. There has not been sufficient time to assess the clinical value of *iso*-nicotinic acid hydrazide. It would greatly surprise the writer if it did not improve upon the results obtained with streptomycin [illegible] Laugie and Routier, 1953; Buchman and [illegible] *iso*-nicotinic acid hydrazide without damage and apparently with considerable benefit. Their papers are worth consulting. For the rest, results with the new drug are mainly limited to talk about lessening of discharge from sinuses, increase of weight, and lowering of sedimentation rate, such as we have heard with each new antibiotic.

VALUE OF ANTIBIOTICS AS ENABLING AGENTS

[illegible] the late 1940's saw patients being treated for sinuses without [illegible] thought has been given to the use of early surgery for [illegible] of the body, with or without abscesses, with the clear aims of shortening the period of treatment and minimizing the local spread of disease before quiescence was achieved. Treves many years ago proposed the drainage of psoas abscesses. Indeed,

Pott himself opened abscesses from the spine by cautery and seton. Secondary infection prevented general adoption, and Cleveland (1935) showed that 50 per cent of patients with spinal disease and secondarily infected sinuses eventually died of their disease. Even before chemotherapy was available certain indications were, however, recognized for opening abscesses, for example, the use of costotransversectomy for paraplegia with thoracic paravertebral abscess. But in general it was felt that the risk of secondary infection upon the devitalized tuberculous tissues was too great. In the last 7 years, however, there have been a number of really important papers by surgeons in England, America, Scandinavia, France and Germany. They have all been concerned with this one question; that is, can tuberculous lesions, granted adequate antibiotic cover, now be treated upon ordinary surgical principles: drainage of pus and the removal of diseased bone? Orell (1951) in Sweden published a series of 100 cases in whom he had practised radical elimination of foci where a joint was not involved, and the evacuation of cold abscesses. In a later paper (Orell, 1952) he has advocated curettage of a calcaneal lesion and capsulectomy with curettage of all diseased femoral and acetabular bone in hip disease. He left a dry powder mixture of 3 grammes of streptomycin and 300,000 units penicillin in the wound and followed by 2 weeks of daily streptomycin and penicillin. In a further paper (1953) he gives details of more cases in which spinal lesions and abscesses were operated upon after careful tomographic investigation of the vertebral bodies.

Macrae (1952) has been treating thoracic paravertebral abscesses by two rib costotransversectomy on both sides under chemotherapy cover, removing all sequestra and debris and irrigating from side to side and has claimed more rapid clinical improvement and bony fusion. Roaf (1952) writes in support of the drainage of paravertebral abscesses and Lindahl (1951) published a striking group of cases of tuberculosis of the greater trochanter treated by open excision and primary closure. He reduced the average stay in hospital from 265 days with conservative treatment only, to 65 days by a combination of conservative treatment and operation with antibiotics. He had followed his 10 cases for 24 months after operation without breakdown of their primary healing. Massart (1950) advocates drainage of closed abscesses and others including Winterhoff and Weber (1948), Hoover (1950), Seree and Dettloff (1950) and Cotrel (1950) write in the same vein, although sometimes without insistence on sufficient post-operative observation. Ostman (1951) claimed 25 out of 27 successful results with healing by primary intention after abscess drainage under streptomycin cover. Hirsch (1951) has adopted the same method of attack both upon spinal disease and sacro-iliac disease with abscesses. For the latter he even added simultaneous bone implants and obtained good heal[illegible]

[illegible]

quent breakdown. Kastert (1951) in Germany has used a similar radical method with the addition of a fine rubber catheter down to the vertebral bodies left in place for 6 weeks so that he might inject streptomycin daily to the site of the lesion.

Aldes (1952) wrote discussing the treatment of Pott's disease with abscess and believes that the thoracic cases should be drained and lumbar abscesses if possible excised entirely by a lateral extra-peritoneal route and as much of the diseased bone cleared as possible. He gives streptomycin and penicillin cover for 1 week before and 2 weeks after operation, but may continue until after spinal fusion which he advocates 4 weeks after the drainage or removal of the abscess. Evans (1952) has published a series of 196 cases from which he deduces that it is quite unnecessary to delay surgery until the disease is quiescent, nor did he find that multiple lesions or an abscess contra-indicated surgery.

Deroy and Fisher (1952) published an important and *stimulating paper* on the treatment of closed bone lesions. They recognized an advancing lesion or abscess formation or sequestrum formation as adequate indications for surgical *intervention* under chemotherapy cover. They opened the lesion, removed all debris, sequestra and pus, and then gauze packed from the bone up to the skin surface. The gauze was removed 10–14 days later and they claimed that healing occurred from the bottom and that nearby joints were not subsequently involved. They also treated 6 cases of sacro-iliac tuberculosis with abscess by curettage and bone chip packing with good fusion results, although they allowed quite rapid remobilization. Their spinal cases likewise did well with the same radical treatment and they claimed more than usually rapid fusion of the diseased vertebral bodies. Wilkinson (1954) has urged operative treatment for disease of the hip in children. If he detects any narrowing of the joint space or increasing bone destruction in cases receiving chemotherapy and conservative treatment he practises anterior partial synovectomy with removal of any obvious diseased bone He has demonstrated a number of these patients for whom he has obtained good ranges of movement after a further short period of immobilization.

All these publications antedate the discovery of *iso*-nicotinic acid hydrazide and its related isopropyl compound. The results should be even better with the antibiotics now available.

Patients with disease of the thoracic spine in the first five years of life present a very clamant problem Very often when first seen there are two vertebrae involved with a small globular abscess. We have all seen these cases under conservative treatment progress by subligamentous spread until a considerable number of vertebral bodies are lost or partially destroyed and gross deformity of the chest and general stunting are inevitable however eventually successful treatment may be in producing quiescence. These children lose not only their stature and physique, but years of their childhood. Should such abscesses be drained and would such immediate intervention result in less spread of the disease? To obtain the answer to this question will require considerable courage.

It must be apparent that one is only as yet able to indicate the lines upon which many minds are working in many countries. Some of the papers published record inevitably only a very short period of post-operative observation but we are faced with the fact that it appears possible to drain tuberculous abscesses and remove tuberculous bone and even to graft or chip-pack the lesions so cleared under chemotherapy cover and to obtain sound primary healing. Whether or no this will in the long run be advantageous to patients in the sense that their period of illness will be reduced, the amount of ultimate bone destruction be lessened and their risk of relapse be smaller, remains to be proved. The answer to this question is, however, of the utmost importance to the future treatment of bone and joint tuberculosis. Orthopaedic surgeons of great experience in this field can still say that such patients are never "cured" and must steel themselves to deal with possible relapses and secondary lesions at intervals. The effect of such breakdowns psychologically and practically is serious. They may and do occur when a new job, a new business or even a new wife or husband have been undertaken. Will it prove possible to replace this cautious fatalism by an early but not foolhardy planned attempt at a cure by surgery aided by antibiotics? There is a great responsibility at the present time to plan treatments for different series of cases with the utmost care and to publish all results whether good or bad.

ESSENTIAL FACTS OF ANTI-TUBERCULOUS CHEMOTHERAPY

Streptomycin

Streptomycin can be given intramuscularly with least pain if the sulphate is used. There is nothing to be gained in therapeutic efficiency or control of toxicity by

dividing the daily dose. The dose which has been shown to combine therapeutic adequacy with a minimum of toxicity has been 1 gramme daily for adults with a reduction for older children to ¾ gramme and for younger children, say under 5, to ½ gramme. If treatment is being given continuously for more than 3 months there will be an increased number of toxic effects unless the frequency is then reduced to, say, three times a week. Indeed, in America, mainly as the result of experience with pulmonary cases, it has been stated (Tucker and Hughes, 1951) that streptomycin 1 gramme twice a week combined with PAS 12 grammes a day is as effective as giving streptomycin daily. However, this has never been proved for orthopaedic cases. Efforts have been made in treating synovial tuberculosis as well as disease of the pleura, pericardium and peritoneum (Streeten, 1949; Staines and Cardenas, 1950; Bull, McMahon, Erwin and Dye, 1952) to utilize the fact (Waksman and Schatz, 1945) that streptomycin works best at a *ph* as near as possible to 9·0. Buffered alkaline solutions with streptomycin for injection into joints and other serous cavities have theoretical backing, but have been little used, and there is no proof that the extra trouble is necessary.

Para-aminosalicylic acid

PAS in orthopaedic tuberculosis has been shown to be of little value alone [illegible] proportion to its direct anti-tuberculous effect; this brings us fairly to the subject of resistance. Continuous PAS treatment results in the organisms in a high proportion of cases becoming resistant to the drug in 6 months, continuous streptomycin produces resistant strains after 42 days in 35 per cent, after 60 days in 50 per cent and after 120 days in 75 per cent. With *iso*-nicotinic acid hydrazide used alone resistant strains appear in 11 per cent in 1 month, in 52 per cent after 2 months and in 71 per cent after 3 months treatment (Joiner and others, 1952). It is clear, therefore, that at the present time we have no antibiotic for tuberculosis which can be given alone. Furthermore, with courses longer than 3 months, and such are frequently advisable, it is probably safer to give three antibiotics, all having an effect against the development of resistant strains, rather than two. It is already clear that *iso*-nicotinic acid hydrazide and streptomycin in sputum positive pulmonary cases prevent the emergence of resistant strains for 3 months, but that thereafter such do appear (Joiner and others, 1952). A report to the Medical Research Council (Report to the Streptomycin in Tuberculosis Committee of the Medical Research Council, 1950) showed that, to exert this effect upon the emergence of streptomycin resistance, more than 10 grammes of PAS daily should be given and preferably something approaching 20 grammes. PAS is an unpleasant drug and the writer has not found that the use of cachets, liquids, keratin-coated capsules, granules or even calcium benzamido-salicylate which only releases PAS after absorption, removes the gastro-intestinal effects entirely.

Iso-nicotinic acid hydrazide

Iso-nicotinic acid hydrazide has been shown to have a synergistic effect when used with streptomycin (Rist, 1952; Rothstein, 1952; Goulding and Robson, 1952) and although the time since its introduction is short and details of its full effect in orthopaedic tuberculosis are necessarily scanty, its known properties encourage optimism. In particular its very much greater ability to penetrate the cell membrane and to inhibit the growth of intra-cellular tubercle bacilli (Mackaness and Smith, 1952; Mackaness, 1952) should give it a very much greater value than streptomycin and PAS. It will do this at 1/200 of the concentration required by streptomycin. Toxic effects of *iso*-nicotinic acid hydrazide occur more frequently with doses of more than 4

milligrammes per kilo body-weight daily and that is probably the optimum dose.

We are now inevitably meeting more cases who have already received chemotherapy and it becomes as important for aspiration or operation material to be obtained for the laboratory for the growth of tuberculous organisms and the testing of their sensitivities to previously given antibiotics as it has been hitherto important for the establishment of the diagnosis. Not only may it be useless therapeutically to give an antibiotic to which the patient's infecting strain has become resistant, but it will also be of no value in preventing resistance developing to any other drug given at the same time. Hence, it should be considered routine whenever circumstances permit for the laboratory to be supplied with material for such tests on orthopaedic cases. We are that much worse off than our colleagues in chest work who with their sputum positive cases can usually assess the therapeutic position with greater ease and frequency. Knowledge of the resistance situation can be of the greatest value and it would often be possible if such routine use of opportunities became accepted practice; indeed more and more will they become essential.

Investigations by Jawetz and Gunnison (1952) have made the question of polytherapy more difficult by showing that when the bactericidal antibiotics (penicillin, streptomycin, *iso*-nicotinic acid hydrazide, bacitracin and neomycin) and the bacteriostatic antibiotics (aureomycin, chloromycetin, terramycin, PAS and sulphonamides) are used together, they may produce a self-neutralizing combination. Terramycin will reduce the value of *iso*-nicotinic acid hydrazide against tuberculosis, but more particularly this question arises when treating patients for secondary infection. The bactericidal antibiotic may be prevented from exerting the effect which it normally has upon actively dividing bacteria by a bacteriostatic drug given at the same time. There is, however, no constancy in these combined effects and many bacteriologists now consider that the correct antibiotic combination for secondary infection should be ascertained in the laboratory upon cultures obtained from the patient. Particularly is it true that the value of penicillin or streptomycin may be lost by the simultaneous use of aureomycin or chloromycetin.

From work with pulmonary tuberculosis it would appear that viomycin (Hackney, *et al*, 1953) in dosage one gramme intramuscularly twice a day on 2 days a week combined with oral PAS 15 grammes a day and INAH 200 milligrammes a day for 3 months may be a useful alternative therapy when the organism is known to be highly resistant to streptomycin or the patient cannot tolerate some toxic reaction of the drug. Similar toxic reactions to those observed with streptomycin can occur, including eighth nerve effects. The combined use of Pyrazinamide and INAH (McDermott, *et al*, 1954) may also have a future but the former is not infrequently toxic to the liver.

There is one general point which has not yet been made. Trauma will often provide the stimulus for reactivation of a tuberculous lesion. It might therefore be worth advising all discharged tuberculous patients that a fall or other reasonably severe injury should be reported at hospital. A course of chemotherapy immediately might prevent relapse. This would be difficult to prove but does not, however, sound an unreasonable prophylaxis.

To summarize, no drug should be given alone, and it is probably best to give all three together always. Optimum dosages are as follows: Streptomycin, 1 gramme intramuscularly once a day; PAS, say at least 15 grammes divided because of its rapid renal excretion into six doses daily; *iso*-nicotinic acid hydrazide, in two or three doses with a total of 4 milligrams per kilo body-weight per day.

CONCLUSIONS

(1) Streptomycin undoubtedly has a beneficial effect upon the natural history of conservatively treated closed bone and joint tuberculosis of the limbs.

(2) Many sinus cases can be healed by streptomycin, but consideration of the x-ray findings, and the use of surgery in combination with antibiotics for those appearing likely to require it, will increase the proportion of successes.

(3) Streptomycin may be used intra-articularly in chronic synovial disease with very real benefit. *Iso*-nicotinic acid hydrazide can also be so used, but its value is as yet unproven.

(4) No chemotherapy should ever be given alone and probably streptomycin, PAS and *iso*-nicotinic acid hydrazide should always be given in combination in the dosages already mentioned.

(5) The value of *iso*-nicotinic acid hydrazide is as yet unproven in orthopaedic disease, but the details already published of its effect in pulmonary cases and *in vitro* suggest that it should greatly enhance the effects already obtained with streptomycin, and streptomycin and PAS in the orthopaedic field.

(6) Six months is the probable wise minimum for a course of antibiotic treatment where there is destructive bone disease. Especially is this true in spinal cases.

(7) Tuberculous abscesses and closed bone lesions of limbs or spine may be opened with expectation of primary healing under antibiotic cover. Such lesions may even be grafted at the same time The precise indications for such interventions in different age groups and at different sites of disease are not as yet entirely clear.

(*See also British Surgical Practice*· Joints—Tuberculosis, Vol. 5, page 219, S Key 207)

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SURGICAL TREATMENT OF INVOLUNTARY MOVEMENTS

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INTRODUCTION

Among the patients suffering from diseases of the basal ganglia there are a small number so possessed by distressing motor disorders, including especially tremor, rigidity and grotesque athetoid movements, that attempt to help them by surgical means seems justifiable.

The diseases themselves are not common, although one patient afflicted with bizarre involuntary movements, and visiting from clinic to clinic, may seem like a multitude. Parkinsonism, to take a well-known example, occurs in less than 1 per cent of patients with various neurological affections (Wilson, 1940). More commonly, as a late result of the epidemics of 1918–1936, one sees post-encephalitic Parkinsonism and recent experience suggests that surgical treatment may offer the most benefit to patients of this particular group.

It must be clearly noted at the outset that these motor disorders are only a manifestation, though often a striking one, of a progressive disease process involving a considerable part of the basal ganglia and brain stem. It should also be recognized that the surgical procedures discussed here are of necessity still largely experimental in nature because of the incompleteness of our knowledge as to the pathogenesis of such motor disorders In a general way, it seems to be true that relief can only be obtained surgically at considerable expense to voluntary use of the limb. Recent studies, however, show that this disadvantage may be largely obviated, and these new developments offer the most hopeful approach to future treatment and to the understanding of the mechanisms underlying involuntary movements.

Detailed discussions of involuntary motor disorders have already been presented in monographs by Bucy (1944), Denny-Brown (1946) and in the research volume on the basal ganglia which contains articles by Alexander (1942), Davison (1942) and others. The recent literature has been reviewed by Walker and Harrison (1951) and by Jasper and Feindel (1952).

ANATOMY AND PHYSIOLOGY

Brodal (1948) defines the extrapyramidal system as consisting of all tracts and nuclei which form the substrate for motor functions, other than the pyramidal tract and its site of origin in the cerebral cortex. The older conception that the pyramidal or cortico-spinal tract is derived mainly from the giant pyramidal cells in area 4 of the motor cortex seems no longer tenable. For example, the detailed studies by Lassek (1950), indicate that only about 5 per cent of the nerve fibres in the pyramidal tract of the medulla have such an origin, some two-thirds of the fibres being derived from cortical cells in front of and behind the precentral motor convolution.

anatomically to include the cortex of the posterior half of the frontal lobe and the anterior half [illegible] ward through

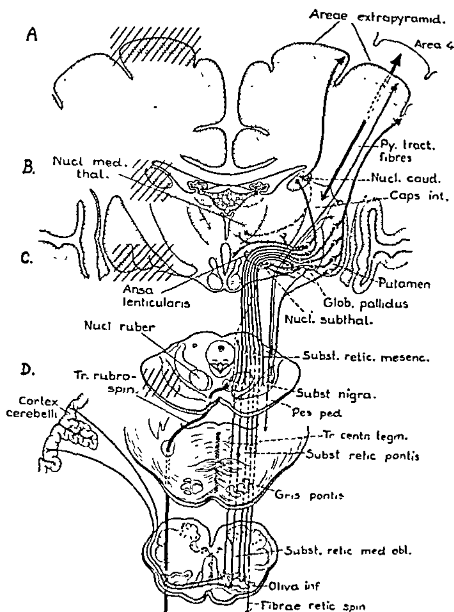


FIG 22.—Diagram of the extrapyramidal pathways On the left the cross-hatched areas indicate the regions where operative interference for involuntary movements has been made. (*a*) Cortex, (*b*) caudate nucleus and internal capsule; (*c*) globus pallidus and ansa; (*d*) cerebral peduncle (*Modified after Brodal*, 1948)

First in line are the caudate nucleus and the putamen which are structurally similar and together are termed the striatum. The putamen in turn is seen grossly to make up the lateral part of the lentiform nucleus, the medial part of which is formed by the globus pallidus. Further intricate connexions (Ranson and Ranson, 1942) exist with the grey matter in the brain stem, including the sub-thalamic body, the red nucleus, the substantia nigra, and, in addition, the reticular formation, which is being more and more recognized as having an essential rôle in motor function.

In a wider sense, the cerebellar nuclei, together with the inferior olive, the pontine

grey matter and the vestibular nuclei, may also be considered in relation to those structures concerned with voluntary movements.

The activity of all these complex structures is eventually funnelled down to the anterior horn motor neurones by direct and indirect motor spinal pathways.

Structures at various levels in this indirect motor system are involved by disease with production of certain characteristic syndromes. However, knowledge of the patho-physiological mechanisms of these disorders still remains obscure and many basic questions in this field require study. For example, retention of a considerable amount of voluntary movement following the excision of the entire cortex of one [illegible] motor disorders.

CLINICO-PATHOLOGY

Certain diseases of the extrapyramidal motor system present fairly well-defined clinical pictures of which excellent descriptions are already available in the literature (Wilson, 1940; Denny-Brown, 1946). Certain points relevant to surgical treatment may be briefly considered here.

Parkinsonism

In his essay on the shaking palsy, Parkinson (1817) described 6 male patients who showed weakness and trembling, difficulty in preserving their upright posture and in performing voluntary movement, and who had slurred speech and excessive salivation. He noted the absence of tremor during sleep. He pointed out that the symptoms seldom occurred before the age of 50 years, and this age incidence presents today one of the many hazards from the point of view of surgical treatment. One of the patients described by Parkinson had paralysis of his right side which came on during sleep. This lasted for about 14 days and during that time no tremor was observed Davison (1944) documents the pathological findings in a patient in whom tremor disappeared, and the rigidity and cogwheel phenomena lessened following thrombosis of a striate branch of the middle cerebral artery. Such instances are sometimes quoted as indicating that the tremor is mediated by way of the pyramidal pathways. It should be pointed out, however, that the ischaemic destruction may involve in addition the pallidum and surrounding area, as in Davison's case, and surgical lesions in this region, with little or no evidence of pyramidal involvement, have recently resulted in abolition of tremor. Davison also points out 6 patients in whom there were pyramidal tract signs and lesions without cessation or lessening in tremor or rigidity.

The two main motor symptoms of Parkinsonism are rigidity of the cogwheel type and a fine static tremor which is more marked in the distal part of the extremities. The tremor tends to decrease during voluntary movements, so that even when present to a marked degree delicate tasks can still be performed. In some patients, particularly in the post-encephalitic group, the rigidity more than tremor may cause interference with useful movement.

Most workers agree that post-encephalitic Parkinsonism is characterized pathologically by cellular damage maximal in the substantia nigra. Some disagreement, however, still exists as to the essential change in idiopathic Parkinsonism. The caudate and pallidum are considered to show the most constant lesion by some (Denny-Brown, 1946), while the substantia nigra shows in this group as well as in the post-encephalitic group the most severe damage according to other observers (Greenfield and Bosanquet, 1953; Davison, 1942). In athero-sclerotic Parkinsonism, there are small perivascular lesions scattered throughout the striatum and globus pallidus, perhaps more exten-

sively involving the latter. It seems important to recognize that even in patients with unilateral signs of Parkinsonism, there may be bilateral pathological lesions.

There is some evidence that damage to the globus pallidus seems essential for the production of rigidity (Davison, 1942; Denny-Brown, 1946), although as a group the post-encephalitic patients show the more intense rigidity and yet exhibit the maximal pathology in the substantia nigra. Davison concludes that disease of the globus pallidus and reticular portion of the substantia nigra results in rigidity, and that lesions of the compact zone of the substantia nigra result in the characteristic tremor of paralysis agitans. It is well known that symptoms of Parkinsonism may also be associated with certain types of poisoning, particularly from carbon monoxide inhalation, and also with tumours involving the globus pallidus and following severe head injury.

Hemiballismus

This is a unique type of disturbance in which there are vigorous rapid repetitive involuntary movements of large range involving the extremities and the trunk on one side. A number of pathological studies have shown that there is damage particularly of the sub-thalamic body (of Luys) on the contralateral side, although the studies of Meyers, Sweeney and Schwidde (1950) suggest that occasionally such movements may be associated with no demonstrable pathology in the sub-thalamic body.

Choreo-athetosis

There are a considerable number of miscellaneous types of involuntary movements associated with various diseases of the basal ganglia. In most of these conditions pathological changes in the striatum, and also in the pallidum, have been observed. Huntington's and Sydenham's chorea, athetoid movements and torsion spasm associated with infantile cerebral palsy, with chronic encephalitis and with some of the rare demyelinating diseases are examples. The pathogenesis of these conditions and the mechanism of production of the more complex involuntary movements remain poorly understood.

INDICATIONS FOR SURGICAL INTERVENTION

The majority of patients with involuntary movements can best be handled by thorough-going medical treatment, physiotherapy, rehabilitation and supportive therapy (Denny-Brown, 1946; Schwab and Prichard, 1951). As Bucy (1951) points out, surgical treatment can never be considered curative and seldom benefits more than one of the many symptoms present in such patients. It seems wise to consider for operation only those patients whose signs are entirely or mainly unilateral. Surgical procedures seem more justifiable also where there is already in existence a degree of hemiparesis from the disease itself.

For convenience of discussion the various approaches to surgical treatment may be considered in the order of the various levels of the extrapyramidal system upon which they are effected (Fig. 22). Emphasis will be placed on the more recent procedures.

CORTICAL EXCISION

[illegible] treatment of involuntary
[illegible] nd the
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excellence of these reports requires [illegible]
Horsley (1909) was the first to do a well-conceived excision of precentral cortex for the abolition of athetoid movements. The involuntary movements which in this instance had involved the upper limb were still absent 1 year after the operation, and

there was a rather remarkable retention of voluntary movement in the hand. The results of similar excisions by Sachs (1935), Putnam (1942) and others add further evidence that tremor and more complex involuntary movements can be abolished or markedly decreased by excision of motor and premotor cortex.

Removal of the cortical representation of the extremities from the precentral motor cortex in man results in a contralateral flaccid paralysis which begins to recover in from 4 to 16 days after operation. The degree of paralysis is always much greater and sometimes complete in the muscles moving the distal joints. Spasticity comes on 1 or 2 weeks after operation and slowly increases in intensity.

Incision of the precentral gyrus, without removal, was reported by Meyers and his colleagues (1950) to abolish hemiballismus. Similar incision was given a careful trial for Parkinsonian tremor in 9 patients (Cobb and his colleagues, 1950) with no evidence of beneficial effect.

SUBCORTICAL OPERATIONS

Direct approach

Earlier attempts to interrupt deep pathways by direct approach through the cortex into the ventricle have been discussed by Bucy (1942), Putnam (1942) and Browder (1948). Meyers (1942), in detailed reports, described improvements in tremor and to some extent in rigidity, following extirpation of the head of the caudate nucleus combined with interruption of fibres in the anterior limb of the internal capsule. Incision in the region medial to the lentiform nucleus by a rather formidable approach through the lateral and third ventricles was also reported to be followed by reduction in tremor and rigidity.

A different anatomical approach to the same region has been described by Fenelon (1950, 1952), who coagulates the ansa lenticularis by means of an instrument inserted through the second temporal convolution. In a series of 11 cases with Parkinsonism 8 were considered to show improvement, especially in the tremor and to some degree in rigidity and slowness of movement. The best results were achieved in patients with unilateral signs and with tremor predominating over the rigidity Absence of pyramidal involvement was a feature noted in this series.

Stereotaxic approach

The recent application of stereotaxic techniques for the accurate destruction of deep-seated structures in the brain presents a more promising approach to the neurosurgical treatment of extra-pyramidal diseases.

Perhaps the most precise studies have been reported by Spiegel and Wycis (1952), and the first volume of their monograph on stereo-encephalotomy describes the technique in detail

Various models of stereotaxic instruments have also been described by other groups, but the actual number of detailed case reports with satisfactory post-operative follow-up examination still remains small.

The significance of the globus pallidus in the genesis of choreiform movements is emphasized by Spiegel and Wycis (1953). Their views have been substantiated by improvement in 3 out of 5 cases of Huntington's chorea in whom electrolytic lesions were produced in the globus pallidus. Talairach, Paillais and David (1950) report improvement of involuntary movements in 1 patient following a similar lesion.

The stereotaxic technique has been most frequently applied to the treatment of Parkinsonian tremor and rigidity. Spiegel and Wycis consider that static tremor is brought about by release of the reticular substance from nigral inhibitory influence, due to degeneration of the substantia nigra. The globus pallidus then exerts an uncontrolled facilitatory influence on the reticular substance, producing tremor.

Destruction of the globus pallidus, therefore, would be associated with reduction or abolition of the facilitatory effect and, with this, of the tremor.

This hypothesis is supported by a number of satisfactory results. Because of the compact anatomical arrangement of down-going fibres in the medial part of the globus pallidus and ansa lenticularis (Fig. 22c), small surgical lesions placed here can interrupt a major portion of the extrapyramidal pathways. Six of 7 patients with unilateral Parkinsonism were improved (Spiegel and Wycis, 1954). In persons with bilateral Parkinsonism the degree of improvement was transitory or partial. In the most successful cases there was marked reduction of tremor with some decrease in rigidity, and of particular note was the absence of impairment of voluntary motor power. A tendency to recurrence of tremor argues for a longer follow-up before this operation can be properly evaluated. The technique has the advantage that the lesion can be made under local anaesthesia so that results are readily assessed. It seems clear that knowledge of the mechanism and treatment of involuntary movements will be greatly enhanced by this approach.

More recently Narabayashi and Okuma (1953) report on 10 patients afflicted with Parkinsonism, who showed a dramatic change in tremor and rigidity but no weakness or hypotonia as a result of injection under stereotaxic control of 1 millilitre of a procaine-oil mixture into the globus pallidus. Some recurrence of tremor was noted after 2-3 months, necessitating a repetition of the injection.

CHOROIDAL ARTERY OCCLUSION

Cooper (1953) reported relief of Parkinsonian rigidity and tremor following surgical occlusion of the anterior choroidal artery. As a result of his experience in some 20 patients, Cooper (1954) suggests that the operation gives the most satisfactory results in individuals under 50 years of age suffering from unilateral post-encephalitic Parkinsonism. Rigidity rather than tremor seems to be improved, although in some cases there was also reduction in tremor.

Complications of the operation include hemiparesis. There were several mortalities in the early series, but these represented patients very severely disabled from the disease. Moreover, limitation of the operation to patients under 50 years of age seems important from this point of view. In the satisfactory results there is little increase in weakness, and indeed usually considerable improvement of voluntary control of the limb because of the reduced rigidity (Bertrand, 1953).

In some patients recurrence of tremor and of some rigidity several months after operation has been noted, but this may be due to failure to close the vessel completely.

Although according to Abbie (1933) hemiplegia, hemianaesthesia and hemianopia comprise the clinical picture following thrombosis of the anterior choroidal artery, this has not always been apparent in the uncomplicated cases of surgical occlusion of the artery. This is probably to be explained on the basis of a collateral overlapping supply from other vessels, particularly from the posterior cerebral and posterior choroidal arteries.

Nevertheless, it is significant that the artery is known to supply the medial part of the globus pallidus, the uncus and underlying amygdala, the anterior part of the hippocampus (Beevor, 1909; Alexander, 1942), and also a small region of the cerebral peduncle and substantia nigra (Abbie, 1933). Alexander has suggested the useful term for this artery, the pallido-hippocampal artery. Occlusion of the vessel would, therefore, be expected to produce an ischaemic lesion which, although somewhat wider in distribution, would include the structures destroyed by the stereotaxically placed lesions noted above. Some disadvantage is presented by the fact that the anterior choroidal artery may be variable in size, pattern and distribution. Moreover, the structure or structures which must be destroyed in order to influence rigidity are

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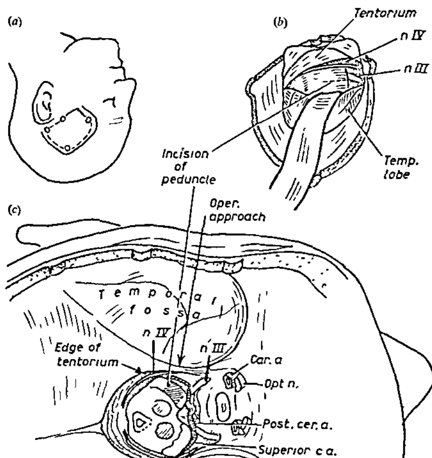
... point of view in the treatment of involuntary movements and rigidity, and will provide considerable incentive to further studies of the anatomical structures supplied by the anterior choroidal artery and their rôle in the production of involuntary movements.

PEDUNCULOTOMY

In order to avoid the severe paresis and the occasional occurrence of seizures and aphasia complicating cortical excision, Walker (1949) has carried out interruption of the cortico-spinal pathway by partial section of the peduncle (Fig. 22*d*).

The cortico-spinal fibres destined to form the medullary pyramidal tract are said ...

From stimulation responses obtained in 8 patients (Penfield, 1952) a definite sequence from mesial to lateral was evident, beginning with face and mouth and progressing to fingers, wrist, arm and foot. Movements of the arm and leg together were often produced from the same point, even at threshold stimulation. This suggests some



Fi...

overlap of the fibres concerned with the upper and lower extremities. The movements were obtained also from a region somewhat wider than the middle third of the peduncle. Both these features might explain the residual motor sparing following partial pedunculotomy, a feature which Walker has already put down to preservation of extrapyramidal fibres which run more centrally to the peduncle and are, therefore, not involved by the section.

Section of the peduncle in monkeys appeared to abolish or reduce static tremor resulting from electrical stimulation of the bulbar reticular formation (Jenkner and Ward, 1953). However, other workers reported complex repetitive movements from

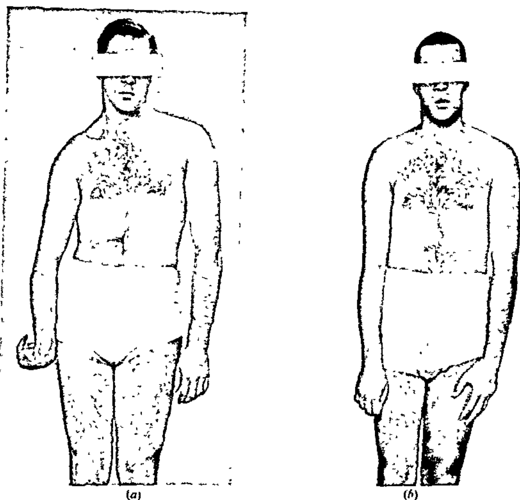


FIG 24.—Posture of right upper limb. (*a*) Before, and (*b*) 3 weeks after pedunculotomy. Athetoid movements were abolished Patient F.L.

stimulation of the basal ganglia, thalamus and amygdala even after trans-section of the cerebral peduncles (Sweet, McCulloch and Snider, 1947).

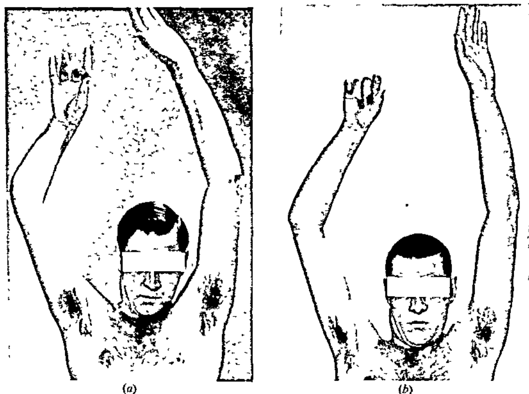
In monkeys complete pedunculotomy is known to produce a contralateral paralysis with hypotonicity but with exaggerated tendon reflexes (Cannon, Magoun and Windle, 1944) In man partial pedunculotomy gives a similar picture. The degree of paresis and hypotonicity is greatest in the immediate post-operative period and gradually improves over the next few weeks. There is actually some tendency to spasticity in the period several months following operation.

With the patient's head in hyper-extended position, approach to the base of the brain may be made through a temporal craniectomy, although a small temporal craniotomy necessitates less retraction on the temporal cortex (Fig. 23*a*). Drainage of

cerebrospinal fluid by way of a spinal puncture needle also permits easier exposure of the peduncle.

After the dura is opened the temporal lobe is gently retracted until the edge of the incisura tentorii and then the peduncle itself comes into view. The fourth nerve and the superior cerebellar artery are usually visible against the lateral surface of the peduncle. More anteriorly the third nerve, the posterior cerebral and sometimes the basilar artery are visualized (Fig. 23*b*). Electrical stimulation may be carried out and the section can be then placed more accurately to involve the appropriate limb (Fig. 23*c*).

The extent of the section has varied with different surgeons. The depth has varied from 3 to 7 millimetres, with an average of about 5 millimetres, and the length from 1 to 2 centimetres. There is also considerable variation in the placement of the



(*a*) (*b*)

Fig 25.—Range of movement of right upper limb (*a*) Before, and (*b*) 3 weeks after pedunculotomy Patient F L

incision, and the evidence so far is still incomplete as to whether the anterior, middle or posterior part of the peduncle should be sectioned. In the patients so far reported in the literature, the section was made in most instances in the middle third or posterior half of the peduncle.

A more anterior section may be indicated if only the arm is involved by the involuntary movements (Fig. 23*c*). The value of selective section on the basis of motor responses obtained from stimulation of the peduncle is well shown by the patient illustrated in Figs 23, 24 and 25. The main difficulty was involuntary athetoid movements of a very bizarre type in the right upper limb, which had been present since infancy. The lower limb, although somewhat rigid, was little disturbed by involuntary movements. The posture and range of movement in the upper limbs before and after pedunculotomy is illustrated (Penfield, 1952) There was some decrease of voluntary movement at the wrist but finger movement was still present. The leg was little affected in tone or power

by the operative procedure. The *involuntary* movements completely disappear 2 weeks the extremities of the right side were less rigid than before. There w increasing spasticity in the arm over a period *of 2 months* after operation, sinc it has remained the same.

In Walker's case, hemiballistic movements were eliminated by section of t terior two-thirds of the peduncle, with the *only permanent* deficit being hemiparesis present 1 year after operation.

Patients with torsion spasm can be helped by *pedunculotomy to the exte* the grotesque writhing *movements are arrested or markedly diminished* and t associated with these movements is relieved (Wertheimer and Mansuy, 1950; P 1952; Hamby, 1953).

The results in treatments of Parkinsonism have been best documented by (1952), who made a section 7 millimetres *deep and 8–10* millimetres long posterior half of the peduncle. Of 4 *patients followed* for *3* years, 2 were relie tremor, 1 was considered to be improved about 50 per cent, and 1 had recurr tremor in 2 years. All 4 patients had a *hemiparesis which was* more marked i with abolition of tremor. He considers the tremor to be helped by interruption cortico-spinal fibres or fibres intimately *associated with them.* Rigidity w changed. In 2 of 4 patients reported by Guiot and Pecker (1949) the trem decreased.

CORDOTOMY

Putnam (1933) has been the main proponent for partial section of the spinal co the treatment of athetoid movements and for tremor. He *sectioned or coag* the anterior region of the upper cervical cord with the intention of interruptin pyramidal pathways, and this gave some relief in milder cases of athetosis (Fig

For unilateral Parkinsonian tremor, Putnam's operation of lateral cord

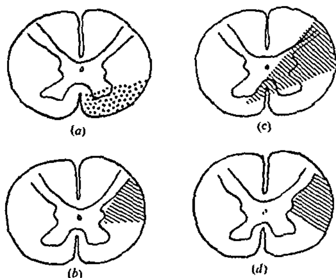


FIG 26.—Diagrams to show of cordotomy in: (*a*) Put anterior section for athetosi various pyramidotomy inc for Parkinsonism carried o (*b*) Putnam; (*c*) Ebin; an Oliver

involving the pyramidal tract (Fig. 26*b*) gave improvement in his first 7 cases (Put 1942). A follow-up study *on* 22 *patients* showed abolition or reduction of trem 15 cases with a moderate or severe hemiparesis in 9 patients (Putnam and 1950). Ebin (1949), using a combined lateral and ventral section to cut the ipsila pyramidal tract and the contralateral anterior column (Fig. 26*c*), reported imp ment of both tremor and rigidity in 11 patients.

More recently, Oliver (1949a, 1949b, 1953), using a somewhat deeper and v section in the lateral column (Fig. 26*d*) than Putnam, has reported benefit in pat

showing tremor as the outstanding disability of Parkinsonism. This section is also carried out at the level of the second cervical segment under general anaesthesia. In 79 patients about 50 per cent are considered by him to show good results. He concludes that cordotomy has a definite, though modest, place in the treatment of Parkinsonism. In severe cases the operation has been done bilaterally.

Following cordotomy there is usually a temporary hemiparesis which passes off in a matter of days. A few patients may show no detectable post-operative weakness. There is a tendency for recurrence of tremor with the return of motor power and the operation in older individuals is not without hazard to life. Whether the relief of tremor is in some degree related to section of not only the pyramidal fibres but also of the reticulo-spinal pathways in the lateral part of the cord, seems as yet uncertain.

CONCLUSIONS

A variety of operative procedures have been applied for the relief of involuntary movements and rigidity. No single procedure seems as yet ideal. Interruption of the pyramidal system, at various selected levels, has benefited tremor but is invariably followed by increased deficit in voluntary power. In the more successful cases this may be only a moderate defect and a forfeit which the patient is willing to offer for the abolition of distressing tremor or athetoid movements.

Further studies of section of the fibres in the cerebral peduncle in relation to stimulation responses may offer improved results from interruption of the cortico-spinal pathways.

Much evidence now indicates that the structures in the region of the globus pallidus are intimately concerned in rigidity and tremor, and small stereotaxically controlled lesions placed in this region seem to offer the hope of the most precise method for relieving involuntary movements without the complication of paresis.

(*See also British Surgical Practice* Brain—Neurological Investigations and Special Tests, Vol. 2, page 385, S Key 75)

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THE APPLICATIONS OF ELECTRONICS TO CLINICAL PRACTICE

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INTRODUCTION

In the last two decades the art of electronics, originally developed for the purpose of communication over wire and through space, has been used to solve problems of measurement and control in an ever-widening range of applications. Science and technology have both benefited from its use, and it is not surprising that in the fields of surgery and medicine electronics has greatly facilitated certain studies of body function which formerly could be made only either crudely or with great difficulty. Indeed, measurements which would otherwise be quite impracticable have now been made a matter of routine. In this review we shall attempt first to explain those basic principles of electronics which are relevant to the present subject, next to consider the wide range of its applications to clinical practice, and finally to discuss some general aspects of the necessary liaison between technology and medicine.

FUNCTIONS OF ELECTRONICS IN CLINICAL WORK

What is electronics? This is a question often asked and almost as often left unanswered. In fact, a satisfactory general definition has not yet been suggested, but although the scope of electronics is difficult to define concisely, its principal functions in clinical work may be summarized as follows.

(1) The detection and amplification of electrical voltages or currents which vary with time, and their modification to any desired waveform.

(2) The display of such waveforms and their recording or storage for future examination or use.

(3) The use of electrical waveforms for control purposes

These three functions are reminiscent of similar functions performed by the nervous system; thus we might express their biological equivalents as follows.

(a) The detection of objective phenomena by the sensory nervous system, and their conversion into suitable forms to be dealt with by the brain.

(b) The "display" of such phenomena by the brain (for example, the step from physical vision to perception), and the memorizing of these phenomena.

(c) The control of body functions by the motor nervous system controlling muscle action.

In addition, when two or more of these functions occur together, the laws governing their mutual behaviour and their stability are strikingly similar in both organism and physical apparatus.

Electronics may be used, therefore, to simulate many of the functions of the

nervous system, and in certain aspects the performance of the inanimate system is superior to the animate in precision. At present, however, it is very difficult to simulate the process of learning; it is necessary instead to build the desired pattern of behaviour into the instrument.

The name electronics was introduced because the principal basic device now employed, the thermionic valve, uses free electrons moving in a vacuum as a "working substance". Free electrons exist, of course, in all electrical conductors, but there their motion is governed by a linear and very inflexible law, the well-known Ohm's Law. Circuits in which only Ohm's Law is obeyed, while being very necessary adjuncts to thermionic valves, cannot be used alone for amplification. For this purpose it is necessary to use free electrons under conditions where their motion may be influenced in any desired manner, for example, by an external voltage.

The use of electronic methods presents certain features which are most valuable in the study of living organisms. Because of the amplification obtainable, it is possible to study and record the extremely minute voltages, often of the order of microvolts only, produced by living tissue, without disturbing the normal tissue functions. Moreover, the extremely small mass of the electron results in its inertia being negligible at normal frequencies, and thus the speed of electronic devices is more than adequate for the examination of the most rapid of biological processes.

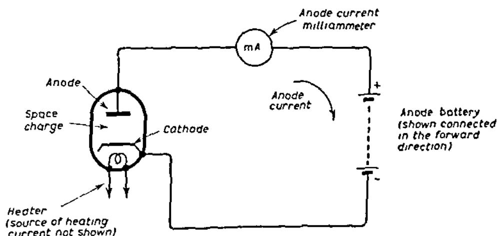


FIG. 27 —Circuit demonstrating the action of the thermionic diode.

These two advantages apply directly to the amplification and examination of electrical quantities only, but it is possible, and in many cases very easy, to convert non-electrical into electrical quantities and vice versa. This is done by a class of instruments known generically as "transducers". The above facilities are therefore available, with certain limitations, for pressures, sounds, light intensities and other physical quantities. It is therefore clear that any physical phenomenon which the body may produce, if it is accessible and distinguishable from its background, may be amplified, examined, recorded, analysed or used for control purposes, by the use of electronic methods.

BASIC PRINCIPLES

Thermionic valves

The processes of production, amplification and modification of changing electrical quantities are carried out mainly by thermionic valves in conjunction with other components such as resistances, inductances, the whole constituting the "circuit". One speaks colloquially of "circuitry" as that part of electronics which deals with the various modes of inter-connexion of the different components. However, it is the properties of the valves themselves which largely determine the final circuit performance, and to them we must turn first for an understanding of what may be achieved.

Diode valve

The simplest valve is known as the diode, because it contains two electrodes. These are enclosed in a glass bulb from which effectively all the air has been removed. One electrode, called the cathode, is heated to dull redness, either by making it in the form of a filament with current passing through it, or by using a tubular cathode heated from within by an electric heater. As a result the energy of the free electrons contained in the cathode material is increased, and those with sufficient energy then escape into the surrounding space. This process does not continue indefinitely, because in a very short time a cloud of electrons known as the space charge forms around the cathode and the negative charge associated with it prevents the further emission of electrons. The equilibrium set up, however, is dynamic rather than static, and there are always electrons falling back into the cathode to be replaced by others leaving it.

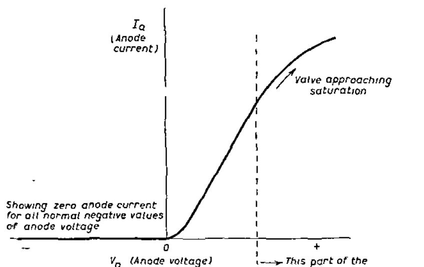


FIG 28 —I_a-V_a Characteristic of the diode, showing the unidirectional nature of its conduction

Surrounding the cathode is a plate of more or less cylindrical shape known as the anode If the diode is connected in the circuit shown in Fig. 27, and if the anode battery is arranged so that the potential of the anode with respect to the cathode is positive, electrons will be attracted from the space charge towards the anode, and being collected by the anode will flow through the anode current meter and the battery back to the filament. Simultaneously the space charge will be replenished by further emission from the filament. Thus an "anode current" will flow through the valve from cathode to anode. If, however, the anode battery is reversed, so that the anode is negative, the space charge will be repelled back towards the cathode, and no anode current will flow. The above anode current is an electron flow, and it has been customary in the past to refer to it as a flow of conventional positive electricity in the reverse direction. This is purely a convention, and throughout this review explanations will all be given in terms of electron current, even when this is not specifically stated.

If the potential difference or voltage (V_a) applied between anode and cathode ...

more electrons will take part and I_a will increase very roughly in proportion to V_a. At very high values of I_a the cathode may not be able to supply all the electrons required to maintain the space charge, and the increase of I_a with V_a is less rapid. When all the electrons emitted by the cathode are immediately collected by the anode,

the space charge ceases to exist and the condition is known as saturation. This condition is usually avoided in the operation of small valves.

This behaviour is shown graphically in Fig. 28, which gives the "I_a-V_a characteristic" of the diode. It is clear that the valve behaves towards an electric current in much the same way as a "non-return" valve behaves in a tube carrying liquid. It is, in fact, an automatic switch operated by the "pressure" of the current which it controls. As such it may therefore be used to rectify an alternating current, that is to render unidirectional a current which is reversing periodically, usually many times per second. For example, direct current which is required for the operation of electronic apparatus may be obtained in this way from the alternating current mains by the use of one or more diode rectifiers in conjunction with a transformer and smoothing circuits.

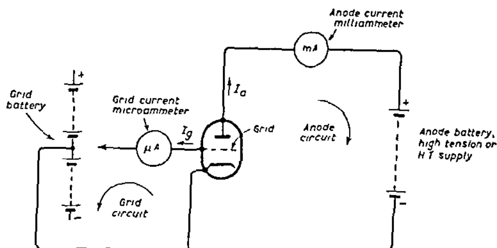


FIG. 29 —Circuit demonstrating the action of the thermionic triode.

Triode valve

Although the diode is the precursor of all other types of valve, its uses are limited, mainly because it does not provide any means of controlling the magnitude of its anode current other than the potential difference in its anode circuit. The inclusion of ... controlled by an

powerful tool which will perform nearly all the functions ...
apparatus. For this reason, and also because most of the more complex valves are no *different in principle, we shall discuss the properties* of the triode and its possible applications in some detail

...ables a variable potential, positive or negative, to be ...d *at cathode potential, the valve behaves as a diode,* ... voltage is positive and constant, anode current flows as shown at point A in Fig. 30. This is so because the grid is in the form of a fine wire helix between cathode and anode, and when *it is at zero potential it does not materially impede the flow of electrons to the anode. If the grid is then made more and more* negative, the anode current decreases progressively because of the repulsion exerted by the negative grid, until at a value of V_g known as *the cut-off voltage*, I_a becomes *zero* (ABC). When, however, the grid is made positive, two changes occur. Because of the additional attraction of the positive grid, the anode current increases (ADE), but also the grid itself behaves as an anode and collects some electrons, *which form a current in the grid circuit.* This is shown by the small grid current curve in Fig. 30.

When using the valve as a normal amplifier it is customary to limit its operation to the region shown. Here the straightness of the curve ensures that I_a *will be proportional* to V_g, and *as the grid is negative it* collects no electrons and I_g is zero. When operated

under these conditions the triode enables a large anode current to be controlled in a linear fashion by a small grid voltage. Moreover, the grid current in this range is nominally zero so that zero power is taken from the source of the control or "signal" voltage. In practice a very small grid current flows, due to factors other than electron emission from the cathode.

The value of this behaviour may best be illustrated by an example from neurophysiology. Let us suppose that two micro-electrodes are placed on a nerve, which is then artificially stimulated. An electro-chemical disturbance travels down the nerve, and as this passes the electrodes, there results between them a rapid change of potential difference which might be a millivolt or less. If it were permissible to take as much current as required from the nerve *via* the electrodes, the detection of this "action potential" would be relatively easy without recourse to electronics, perhaps by using a string galvanometer as in the electrocardiograph. But the connexion of such an instrument, taking a current of the order of a microampere from the nerve fibre, would seriously disturb the normal functioning of the nerve and might, in fact, block the impulse completely. If, however, we connect the electrodes between the grid and cathode of a suitable triode, the current drawn may be less than one micro-microampere (10^{-12} amp), and the change of potential on the grid will produce a corresponding change of anode current, which, because it represents a much larger amount of power, may be easily displayed or recorded by methods to be described later The triode is therefore often described, somewhat inaccurately, as a "voltage operated" device, not because it operates with zero input current, but because in most applications the input current may be made negligible compared with the current actually available from the source. The circuit used is shown in Fig 31*a*, where the voltage to be examined, or the "signal", is shown diagrammatically as an alternator, and the "grid bias" battery serves to bring the valve to its normal working point as in Fig. 30.

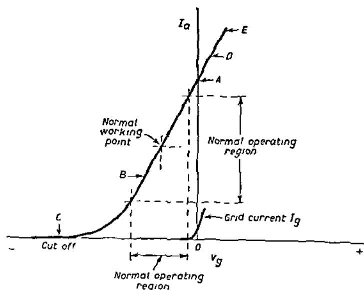


FIG 30—I_a-V_g. Characteristic of the triode, showing the control action of the grid.

Use of triode valves.—We may now consider the various ways in which triode valves may be used in electronic circuits. In many cases tetrodes or pentodes will be found in practice, but their fundamental behaviour is simply that of the triode. In the application described above the valve is being used as a power amplifier, and the output is in the form of a varying current, which would be suitable for operating a low impedance device such as a pen recorder. Frequently, however, the apparatus follow-

ing the valve, for example, another valve or a cathode ray tube, is of high impedance and hence requires a voltage input. Then a resistance called the *anode load* is connected in the anode circuit, as shown in Fig. 31*b*. The varying anode current flowing through this resistance produces a varying voltage drop across it, and this potential difference or the potential difference between anode and earth forms the output of the stage. The valve is then behaving as a voltage amplifier, and its amplification or gain is expressed as the ratio of output to input voltage.

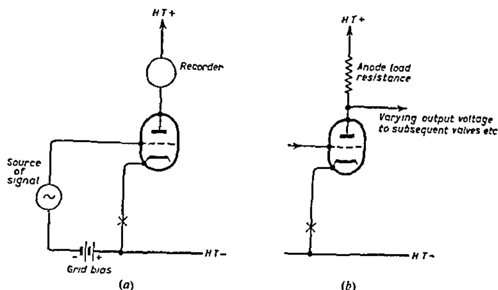


FIG. 31.—A triode amplifier: (*a*) With current output; (*b*) with voltage output.

In the two applications so far considered, the function of the triode is to produce a change in output voltage or current which is proportional to the change of input voltage. This will occur only if the valve characteristic is perfectly linear over th working range, and this is impossible to achieve in practice. Moreover, the chara teristics of any valve will change quite markedly with age or with changing supp voltages, and hence the amplification produced by a simple amplifier is neither line nor constant. There are two methods commonly adopted to overcome these defect and it is notable that the human body makes use of precisely similar methods to stabili its performance and to render it more independent of outside influences.

The first method is applied to conventional amplifiers as described above, and i known as negative feedback. It consists in arranging the circuit so that a sample c ... compared with the input. If the tw ... esired, the output is modified until i ... is point, if a man wishes to take hol of an object, the extent of the initial movement of the hand towards the object ma be partly pre-determined by experience, but if it were not for the feedback link pro ...

The principle may very simply be applied to the amplifier ... a resistance in series with the cathode connexion at X. This "feedback" resistance is thus in both anode and grid circuits, and if the anode current increases as the result of a grid voltage change, the potential difference across the cathode resistor will increase, and this acts as an additional grid voltage tending to oppose the initial change. Thus the effective gain is reduced, but linearity and stability are increased, and the negative feedback principle is of very great value in the design of electronic equipment.

In the second method, the attempt to make valves linear and reproducible within

fine limits is abandoned, and an "all or nothing" mechanism is used which is an exact analogue of that in the nervous system. Under these conditions the valve functions exclusively as a switch, having only two stable states with values of anode current corresponding to grid voltages of zero and cut-off. The "switch" is thus "on" or "off" respectively, and precise values of current are not important. The valve is then said to work under pulse conditions, and trains of current and voltage pulses are a feature of such circuits just as they are of the nervous system. The method cannot, of course, be used directly for the amplification of varying voltages, but it has many other uses, of which radar is a familiar example whose reliability is mainly due to the use of pulse circuits.

Valve amplifiers and switches may, with simple modifications, be used for the production of voltage and current waveforms of any shape. Valve oscillators are derived from amplifiers and switches by applying *positive* feedback in the circuit. The linear amplifier then produces sinusoidal voltages and currents, and the valve switch produces pulses Familiar examples are respectively the short wave diathermy generator and the electronic muscle stimulator (Hay, 1952). It was seen above how the application of negative feedback in the form of a voltage *opposing* the input voltage resulted in reduced gain but increased stability and linearity. Similarly, a voltage fed back from the output which *assists* the input voltage is called positive feedback and increased gain but reduced stability result. If the feedback is sufficient the amplifier or switch may be made to supply its own input, it then becomes a generator of varying currents and voltages

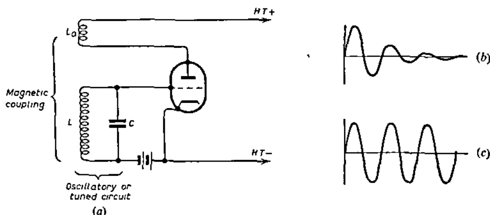


FIG 32—(*a*) A triode oscillator to produce sinusoidal currents, (*b*) currents in the LC circuit with energy loss in stray resistance, (*c*) currents in the LC circuit with energy losses made up by positive feedback from the anode circuit

Fig 32*a* shows a simple triode amplifier which will behave in the above manner, the coil and condenser in the grid circuit behaving together as if tuned to a certain frequency. The behaviour is entirely analogous to that of a mechanical vibrating system, for example, a mass on a spring, in which the mass corresponds to the inductance L, and the stiffness of the spring to the reciprocal of the capacitance C. For example, a metal strip or reed clamped at one end may be made to vibrate at its "natural frequency", and, as in the electrical circuit, this frequency may be varied by altering the mass and stiffness of the reed But because of energy losses in the form of air friction the oscillations of the reed die away rapidly, and in the absence of the valve so would the electrical oscillations in the LC circuit (Fig. 32*b*), in this case because of energy losses in stray resistance The first oscillations of the circuit, however, are applied to the valve as a voltage input, and an anode current of the same waveform but representing much greater energy is produced. This current is passed

through the coil L_a *and energy is fed back to the grid circuit in the correct sense via* magnetic coupling. Thus the losses are compensated and the circuit "oscillates" continuously (Fig. 32*c*). Moreover, excess energy of the same waveform is available for use outside the circuit. When used in this way the valve again does not produce energy from nothing but merely converts energy from the direct current supplies into the desired form. Voltage and current pulses may be produced in a very similar way by applying positive feedback to a triode switch, but for practical reasons it is necessary to use two valve switches working together. Such a circuit is known as a multivibrator and it forms the basis of most types of muscle stimulator.

The simple functions of thermionic valves described above underlie most other more complex applications. For example, valve circuits may be used for counting events such as the arrival of ionizing particles emitted by a radio-isotope, but the valves in this case act simply as interdependent switches operated by electrical pulses produced by the incoming events.

Methods of display

Returning to our example from neuro-physiology, when the minute voltages produced *by the nerve have been satisfactorily amplified to a high level by one or usually* many valves, they must be presented to the senses in intelligible form. The simplest display method employs a loud speaker or headphones which transform the currents ... with time into varying air pressure. *Thus the ability of the ear to discriminate*

... The method is valuable in routine

... But its main disadvantage is the indifference of the ear to phase relations; *it will only indicate the amplitudes of the* frequency components of a complex waveform, information which does not completely describe the characteristics of the waveform.

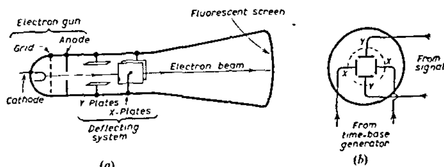


FIG. 33.—(*a*) Cross-section of a simple cathode ray tube, (*b*) front view of the tube showing the four deflector plates

Cathode ray tube

To display a waveform unambiguously, the time scale must be converted into a distance, and the values of current or voltage plotted against time as the *X-co-ordin-* ... and it is fortunate that we

... cathode

ray tube.

Fig. 33 shows such a tube in cross-section. Electrons emitted by the cathode are attracted by the anode system (which is usually more complex than is shown here) ... the beam and strikes the end

... tial. The

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visible light when bombarded with electrons, and ... circular screen. The brightness of the spot depends on the electron current and hence on the grid potential, but its position is controlled by the two pairs of deflector plates

between which the beam passes. Clearly the application of a potential difference between, say, the X plates will result in a deflection of the spot to the positive side, and so on. In practice, the signal to be examined is usually applied to the Y plates, and a voltage of saw-tooth waveform to the X plates. In the absence of a signal, the latter voltage causes the spot first to travel across the screen at a constant and easily controlled speed, and then to fly back to its starting point as rapidly as possible. If the signal consists of a periodic waveform, the X voltage or time base voltage is made to repeat periodically with a frequency equal to that of the signal or a submultiple of it. Thus consecutive traces coincide on the screen, and due to the persistence of vision and of the phosphor's luminescence, an apparently stationary waveform is produced. If the voltage to be examined is non-periodic, as will often be so in biological work, it is usually possible to cause it to initiate a single horizontal traverse of the spot. This again will produce a stationary waveform which may, however, vary in intensity due to its variable frequency.

The importance of the cathode ray tube in the display of waveforms matches that of the triode in its own sphere, for very similar reasons. The small mass of the electron permits the examination of very fast phenomena occurring in times of the order of millimicroseconds. Like the triode, the current drawn from the signal source, in this case the deflector plate current, is minute, and finally a two-dimensional display is possible. In fact, a rudimentary third dimension may be added if at the same time the spot brightness is varied by the application of a varying voltage to the tube grid. Tubes in which the electron beam is split and which permit the display of two independent signals on the same time scale are commonplace, and three and four beam tubes are now becoming available. In most cases photography of the waveform on the screen is simple, and analysis of the waveform for a variety of purposes is possible using shaped masks and photo-electric cells

Storage and recording methods

In many applications waveforms must be stored for varying periods of time. Short period storage may be used for delay purposes, while examination and analysis at leisure are possible with semi-permanent records Finally, permanent storage is essential in clinical work where it is desired to keep records of individual patients. The choice of method must depend on a number of factors, such as the permanence required, the frequency range to be covered, whether or not the record must be available immediately, and not the least important, the cost of the material used.

Photographic methods, although expensive, are perhaps most satisfactory, and of these, *photography of the cathode ray tube screen serves well for all frequencies* encountered in biological work. In general, two distinct methods are available. In the first, the tube is operated as for visual work with the time scale produced by a voltage applied to the X plates, and a stationary film is used. In the second, the spot is deflected by the signal in the Y direction only, and the film moves horizontally at constant speed, thus providing a continuous time scale of any desired duration and speed. The first method is suitable for periodic or frequently recurring phenomena, while the second is most valuable when it is necessary to record rare or isolated events.

For frequencies up to 1000 cycles per second, moving coil mirror oscillographs may be used, and these have the advantage of sensitivity, simplicity and portability. Therefore, they are used in conjunction with a continuously moving strip of photographic paper in some well-known portable electrocardiographs.

When records are required immediately, various forms of pen recorder are available. These consist of a large moving coil movement with an arm about 2 inches long attached to the coil and carrying some form of stylus at the end. If the arm is made of thin steel tube, ink may be fed from a reservoir to the stylus which then writes directly on a moving strip of ordinary paper. Sometimes a solid arm is used, and then an

electric discharge passes from the point through specially sensitized paper to a fixed electrode below. This method gives a very fine trace, but the paper is expensive and the small spark produced may be dangerous in the presence of ether vapour. This latter disadvantage applies also to the type in which the moving arm carries at the end an electrically-heated loop which records on heat-sensitive paper. Whatever the method of marking the paper, the presence of the long stylus arm greatly increases the rotational inertia of the system and the direct writing pen is limited to frequencies of the order of 50 to 100 cycles per second. This, of course, is no disadvantage in applications such as electroencephalography and routine electrocardiography.

All the above methods yield visible records, but for some purposes it is sufficient to record the electrical potentials in such a way that they are not immediately visible, but may be played back at any time for examination or visible recording. Here magnetic tape recording is outstanding and its growing popularity in the business and entertainment fields perhaps makes description superfluous. It is sufficient to say that its frequency response extends from about 30 to 10,000 cycles per second, and it is difficult to record frequencies below this range. Special methods are therefore required for the slowly varying potentials often encountered in clinical work.

A summary of storage systems would not be complete without reference to the methods used in electronic computers. Of these, magnetic recording has already been described, and the only other of immediate interest in clinical work is the storage of a train of events in the form of a pattern of electric charges on the inner surface of a cathode ray tube screen. This pattern of charges is produced by the electron beam scanning the screen, much as in a television receiver, and although the charges tend to leak away fairly rapidly, they may be regenerated during each complete scanning operation and may also be "read off" at any desired time. The method is possible with ordinary cathode ray tubes, but better performance is obtained from special storage tubes now becoming available.

APPLICATIONS

Although in this article it is neither possible nor desirable to catalogue every application of electronics to clinical work, examples will now be given which will illustrate generally how electronic methods can assist the clinician. Various methods will be grouped for consideration and the special features and difficulties of each will be discussed.

Electrical quantities

The electrical phenomena produced by the nerves and muscles of the body are usually too small for convenient observation without the aid of electronics. In the heart, however, many muscle fibres contract simultaneously, and although the voltages produced at the electrodes are small, of the order of millivolts, the current available is relatively great. Hence a simple indicator such as the string galvanometer may be employed, its useful frequency range extending to about 500 cycles per second. But even in its recent forms this instrument is relatively fragile and inflexible, and in modern electrocardiography it is now being displaced by pen recorders and moving coil mirror galvanometers associated with valve amplifiers. This combination is generally more portable and convenient in use, and its flexibility is due to the ease with which many different quantities may be simultaneously recorded, either the various electrocardiographic "leads" or other variables such as respiration and blood pressure.

Valve amplification

In the study of action potentials from small masses of muscle and from the nervous system, however, the voltages and currents available are both minute, and valve amplification is essential. The design of such electro-physiological amplifiers presents

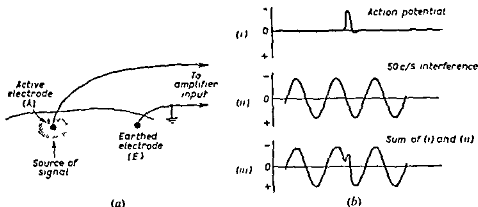


FIG 34 —(a) Monopolar electrodes applied to tissue; (b) voltage waveforms at "A", "E" assumed at zero potential

special problems which must be solved if the desired signal is to be obtained free from interference. In Fig. 34*a* is shown diagrammatically a mass of tissue with monopolar* electrodes in place, consisting of one active and one earthed electrode, while Fig. 34*b* shows the voltage waveforms at point A over the source of the signal. A single action potential is shown in (i), while (ii) is a voltage induced from the 50 cycles per second mains supply, such as can occur in the absence of perfect screening. Curve (iii) shows the total effective voltage fed to the amplifier input, and although in this case the interference depicted is roughly of the same amplitude as the signal, in practice it may be ten or a hundred times as great. It is clear that this arrangement will not be satisfactory unless the patient is enclosed in an earthed metal cage which will exclude electric fields. This is inconvenient and costly, but even then monopolar electrodes are suitable only when there are no interfering potentials from the rest of the body. In general, greater spacing between two electrodes results in disturbances being picked up from more distant tissues, and hence with monopolar electrodes of the type shown it is extremely difficult to eliminate interference from the heart muscle, which produces relatively large currents in all parts of the trunk.

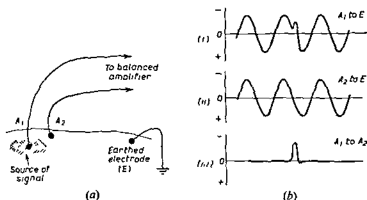


FIG 35 —(a) Bipolar electrodes applied to tissue, (b) voltage waveforms.

For these reasons it is best to discard the earthed electrode (E in Fig. 34) and to employ two similar bipolar* electrodes each of which is independent of earth. These electrodes are positioned close together so that they are affected equally by distant disturbances, but differentially by any nearby signal. For example, Fig. 35*a* shows electrode A_1 over the source of the signal and A_2 some distance away. In Fig. 35*b*, (i) and (ii) show the potential differences between both electrodes and earth respectively,

*The terms monopolar and bipolar are used in this context with the special meaning indicated, although in each arrangement, of course, there are two electrical "poles" present.

one containing signal and interference components and the other interference only. Now if A_1 and A_2 are not more than a few inches apart, the interference voltages induced in each from relatively distant sources such as alternating electric fields and body functions will be equal. Hence if the bipolar electrodes are connected to a special amplifier the input circuit of which is effectively isolated from earth, and which responds only to the *difference* [illegible] fier output will be a replica of curve [illegible] The system will then be relatively [illegible] effective range of the pair of electrodes A_1, A_2. Further electrodes A_3, A_4 may now be added, and each pair A_1A_2, A_2A_3, A_3A_4 may be connected to a separate differential amplifier. There will then be no mutual interference although each electrode may be common to two channels.

In practice it is difficult to use the simple amplifier depicted in Fig. 31 in this way, as the input lead connected to the cathode side cannot easily be dissociated from earth. It is clear, however, that any electrode connected to a valve grid is almost completely isolated from earth, and the ideal differential input stage contains therefore two triodes in a "push-pull" or balanced circuit (Fig. 36*a*), each grid being connected to one electrode of the bipolar pair. If now the valve gains are exactly equal, zero anode-to-anode voltage will result from the equal components of interference voltage picked up by electrodes A_1 and A_2 of the bipolar pair. Only the differential signal voltage will result in an effective output. This condition of equal valve gains, however, is very difficult to achieve and much more difficult to maintain even over short periods with two independent voltage amplifiers, and in practice the principle of negative feedback is used. This is done in the "long tailed pair" shown in Fig. 36*b* by using a common cathode resistor, which reduces the gain of the stage to less than unity for interfering signals without affecting the differential gain.

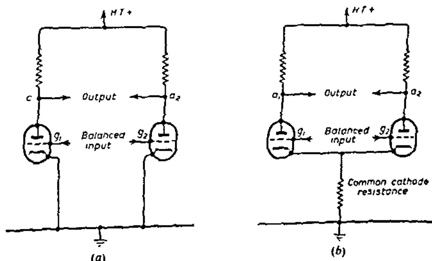


FIG 36.—(*a*) Simple differential amplifier, (*b*) differential amplifier with common negative feedback or "long tailed pair"

This circuit is very stable and "self contained", in that it neither disturbs other circuits by interaction through common power supply leads nor is disturbed by them. The curvatures of the two valve characteristics, being opposite, tend to balance out and linearity is greatly improved. For these reasons, a physiological amplifier will very frequently contain nothing but long-tailed pairs connected in cascade, the general form being shown in Fig. 37. The pre-amplifier, which is usually battery operated for reasons of stability and absence of 50 cycles per second interference from power supplies, may contain two double triode stages, with a total gain of about 1000.

Its output is fed through a gain control and frequency controls to a main amplifier consisting of two or three balanced stages, and thence to display and recording units, all mains operated. The gain of the main amplifier may be 1000 to 5000, and thus the over-all voltage gain is of the order of one to five million. A cathode ray tube requires about one hundred volts of signal applied to its deflecting plates, and therefore a pre-amplifier input of the order of 20 to 100 microvolts would produce a convenient trace on the screen. Most physiological potentials as collected by the electrodes are of this order or larger, and this is fortunate because there exists a lower limit of some 2 to 10 microvolts beyond which signal voltages are swamped by electrical noise produced by the random movements of electrons in valves and conductors. The noise originating in the first stage of the amplifier is, of course, amplified most, and hence the design of this stage is of paramount importance and can make the difference between success and failure. It is interesting to note that this noise limitation is fundamental and could be reduced significantly only by cooling both amplifier and tissues to very low temperatures

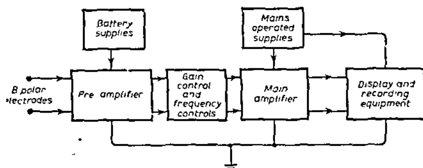


FIG 37 —Block diagram of typical physiological amplifier

Some electro-physiological techniques

Electrocardiography.—We may now consider some specific electro-physiological techniques Electrocardiography is perhaps the oldest of these, and during recent years the major developments have been the introduction of more convenient apparatus using valve amplification, the adoption of new electrode positions, and a new method of displaying the waveforms known as vectorcardiography. With few exceptions, new instruments use balanced amplifiers and either mirror oscillographs recording on photographic paper or pen recorders using an electric discharge or a hot stylus. In one instrument, an ingenious and somewhat unusual method has been used to eliminate the inertia of the pen, a moving coil oscillograph directs a fine jet of liquid which impinges on a treated strip of paper thus producing a record which needs no development. Frequencies up to 500 cycles per second may be recorded, and satisfactory results have been reported. Apart from portable electrocardiographic apparatus, instruments are available which operate in conjunction with a standard electrocardiograph, and which display the record continuously on a cathode-ray tube screen suitably mounted for use in the operating theatre. These should be of great value in all cases where it is desirable to observe the condition of the heart continuously.

Vectorcardiography.—Vectorcardiography is interesting because it abandons the use of a time scale for display, and instead applies the voltage from two pairs of bipolar electrodes after amplification to the X and Y plates of a cathode ray tube. From the resulting pattern the time relation between the two voltages may be deduced, and this provides more information about the orientation of the heart than could be obtained from a single recording or even from two conventional traces.

One application of the electrocardiograph illustrates well the use of electronics for control purposes. If it is desired to radiograph the heart at any particular instant

during its cycle, the electrical pulse representing the QRS complex may b operate a valve switch which controls the x-ray set. This would expose the after the peak of the pulse, but it is then possible by means of a suitable del to produce an output pulse at any desired instant after the QRS pulse, thus any later part of the cycle.

Electromyography.—The clinical applications of electromyography have been described in this work, and we shall confine ourselves to a short descr the equipment. Both surface and intramuscular electrodes are used. The forme of chlorided silver discs covered by gauze soaked in saline, or sometimes sil filled with electrode jelly, and are placed an inch or two apart on the ski effective range of pick-up is relatively large, and thus their output after ampl appears as a summation of action potentials from many different motor unit muscular electrodes may take the form of an earthed hypodermic needle thr centre of which is sealed an insulated wire, the end being ground flush with th point. This wire is connected to the grid of the amplifier. (The conventional b amplifier may be employed with the unused grid connected to earth.) The r inserted into the muscle, and as the two electrodes are very close together, the pick-up volume is small, interference problems do not arise, and action p from single motor units or even from single fibres may be recorded.

The amplifier is conventional (Fig. 37) and the output is displayed on both a ray tube and a loud-speaker. Various types of action potential produce chara sounds which may readily be distinguished aurally, thus leaving the eyes observation of the patient. Recording is usually done by photographing the sc a second cathode ray tube which is in parallel with the first. It may be, howev the particular type of muscle activity looked for occurs only infrequently, examination of twenty minutes to half an hour may be necessary to reveal i continuous photographic recording would be extremely expensive, and it is p to make use of magnetic tape recording to act as a memory of short duration (Ba 1950). Signals from the output of the amplifier are displayed on a cathode ray tu are also fed to a magnetic recorder carrying an endless loop of tape giving 2 seconds continuous recording. The signals impressed on the tape are contin erased, so that at any instant the tape carries a record of what has been seen the preceding 1½ to 2 seconds. If an event of interest occurs, the operation of switch prevents the erasure of the material already recorded, and simultaneou recording function is suspended The output from the tape is then played bac the cathode ray tubes and the loud speaker. At first the whole cycle of rec material is visible on the screen, but it is then possible to select any desired port this by expanding the time scale and to display and photograph it. In this wa those phenomena which are of special interest are permanently recorded and th a great saving in cost and time.

In electromyography there is now a trend which is already firmly establis electroencephalography, namely, the analysis of the voltage waveforms obt The electrical pulse produced by a motor unit consists of the summated action p tials of all its muscle fibres, and if they are under the normal control of the n nerve their effects will occur almost simultaneously and the resulting pulse w short, although longer than the individual fibre potentials. If, however, the fibr to function simultaneously the summated pulse will be much longer and of l amplitude. To obtain the length of the pulses directly it is necessary to photo and measure them, and an alternative method is to make use of the fact that a sh pulse contains components of higher frequency. Thus the summation of a nu of motor unit pulses as obtained from skin electrodes may be fed into a frequ analyser, and the resulting frequency spectrum will be an indication of the leng the pulses forming the signal. It may also be of interest to know when different m

units function synchronously, a sign which is characteristic of some diseases of the spinal cord, and this may be done by having two amplifier channels connected to the two motor units and observing synchronism by means of an electrical coincidence circuit which gives an output pulse only when two input pulses occur within a small fixed time interval. In fact, a simple development of this circuit enables the coincident pulses to be expressed as a percentage of all motor unit pulses in either or both channels.

Computation.—This trend towards the analysis of results illustrates a very important function of electronic circuits, that of computation. The frequency analysis and the coincidence studies described above could both be performed with infinite labour by graphical analysis of photographic records, but circuits exist which will perform almost every mathematical operation more quickly than the human brain and hand. This, of course, is common knowledge, but it may not be so widely realized that the facility is not limited to computing machines in which numbers are fed in from accumulated data, but is also available to operate directly on data obtained electrically from biological and other material. It may be that much experimental work would be facilitated if the existing electronic apparatus were terminated by a simple computor which would produce the results in a more convenient form.

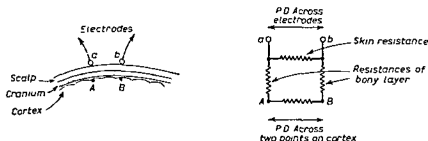


FIG 38 —Electroencephalography. Electrodes and equivalent circuit of tissues.

Electroencephalography —Space does not permit us to do more than refer to the use of electronics in electroencephalography, and indeed the principles are by now well known. It does, however, afford an example of the difficulty of amplifying and recording an effect which is relatively inaccessible Electrical potentials produced in the cortex are of the order of 100 millivolts, but surface electrodes on the scalp receive only about one thousandth of this Fig 38 shows the arrangement of tissues and its equivalent electrical circuit, and it is clear that the cranium interposes two high resistance paths in the circuit, while the superficial tissues of the scalp act as a relatively low parallel resistance. The resistance network thus formed seriously attenuates the signals, and it is not possible to compensate this by increasing the amplifier gain, because of the limit of about 2 microvolts set by random noise in the first stage. This point illustrates the over-riding importance of obtaining the best possible signal before it reaches the electronic equipment, a principle which applies alike to neurophysiological work and to the domestic radio receiver.

Clinical electroencephalographic work today demands six to eight independent amplifier channels, with a corresponding number of surface electrodes; with this arrangement the spatial distribution of potentials over the scalp may be more rapidly investigated. Ink-writing recorders are almost universal in routine work, but reference must be made to recent work in which about twenty amplifier channels operate as many small cathode ray tubes arranged to depict a plan view of the head, each tube giving a special display of the phase and frequency of its input. In addition, as a routine procedure some workers analyse the waveforms into their constituent frequencies, an application of the principles of computation described above which is said to give more exact and reliable information than simple visual analysis. For

accounts of these and other more recent developments reference must be made to the very adequate literature of the subject.

Non-electrical quantities

The transducer

Quantities such as pressure and light intensity must first be converted proportionally into voltages before they can be amplified and displayed. This is done by a transducer, and as this is the source of the electrical signal, the performance of the whole system depends on its design, which is critical and often very difficult. The properties usually required in a transducer are stability and speed of response, linearity and high efficiency. Furthermore, it must often operate in very exacting situations, for example in a blood vessel, without materially disturbing the normal function of the organ. In most cases the performance of the system is limited mainly by the transducer characteristics.

Often the choice of transducer seems obvious, but it is well to consider exactly what the instrument is measuring. This point is well illustrated by the measurement of mechanical movement with the ballistocardiograph. In order to obtain information about the momentum of the mass of blood passing rhythmically through the heart, the patient lies on his back on a smooth rigid surface and the reaction of the moving mass of blood on his body mass causes the whole body to oscillate longitudinally, the necessary freedom of movement being supplied by the elasticity of the superficial tissues on which he is supported. This rhythmic body movement has been converted into a voltage in a number of different ways. In one, a light shutter is moved to and fro by the body across a beam of light impinging on a photo-electric cell, the luminous flux and hence the output voltage being proportional to the body's *displacement*. In another, a light rod attached to the ankles carries a magnet which oscillates near a coil connected to an amplifier. Here the induced voltage is proportional to the rate of change of magnetic flux through the coil and hence to the body's *velocity*. Thus the two methods will give two fundamentally different types of record, however superficially similar they may appear, and it is important in comparing results from different sources to have this clearly in mind.

Measuring intra-vascular blood pressure

Perhaps the most important application of electronics in the field of body mechanics is the measurement of intra-vascular blood pressure. Here the problem is funda- [illegible]

different conditions; in one, the pressure sensitive transducer [illegible] blood stream through a short hypodermic needle, and in the other, the point at which the pressure is to be measured is relatively inaccessible, for example in catheterization of the heart. Piezo-electric crystals and resistance strain gauges have been used in pressure transducers, but the capacitance type of gauge seems to predominate. We shall discuss its design in some detail as it is an excellent example of the conflicting requirements imposed by clinical work.

Fig. 39 shows a simple capacitance pressure gauge in cross section. A volume of saline communicating with the blood stream through a hypodermic needle is bounded on one side by a flat metal diaphragm of considerable stiffness. On the other side of [illegible] millimetre from it, is an insulated electrode which [illegible]

elasticity. The condenser plates will move [illegible] increase. This change is converted by some form of electronic discriminator circuit into a voltage change, which may thus be amplified and recorded. The relation between capacitance and pressure is linear up to a certain percentage deformation of the

technical development is needed, but it is certainly capable of making a great cc tion to the study of the dynamics of blood flow.

Acoustics

In clinical applications of acoustics electronics can play an important rolı apart from the well-known methods used in the diagnosis and palliation of de The stethoscope is an instrument of limited acoustic potentialities which o great clinical success to the sensitivity and selectivity of the human ear. Thus attempt to record chest sounds graphically it has been so far thought neces produce a record which will give rise to a visual pattern related to the origina impression. This is not easy, and it is probably the reason for the limited applic of the phonocardiograph at the present time. In this electrical counterp the stethoscope (Leatham, 1949), heart sounds and murmurs are picked a microphone attached to the chest wall. The electrical output of the microph then amplified electronically and fed either to earphones or to a visual rec Frequency correction is necessary in the amplifier for two reasons. If earphon used, the overall response of the system must be the same as that of the stetho For a graphical record, however, to convey the same kind of impression as the s heard *via* stethoscope or earphones, the response of the system must be f modified to include the characteristics of the average human ear at the pre intensity level of auscultation Broadly, this is done by reducing the low freq response of the amplifier to simulate the well-known Fletcher-Munson curves resulting record is then interpreted visually, usually by comparison with the sounds as heard in auscultation. In this way heart murmurs may be detected, in cases with somewhat greater ease than with the stethoscope; also their ti in relation to the heart cycle may be more accurately determined. At the present it seems that phonocardiographic techniques are largely empirical, and a com review of fundamental aims and methods might yield results far in advance of any so far achieved.

Ultrasonic energy

Sound waves introduced into the body may also be used to detect mecha discontinuities in tissue (Mayneord, 1953*a*). Ultrasonic energy in the form of p is produced by a suitable transducer operated by a valve oscillator. This ener communicated to the body by placing the transducer close to the skin and fillin intervening space with a film of oil. If a discontinuity exists, energy is reflected from it and a delayed series of pulses of energy arrive at the transducer. These displayed together with the transmitted pulses on a cathode ray tube, and a mea of the delay time gives the depth below the surface of the discontinuity.

Television

In many fields such as the measurement of temperature and of visible and ul violet light intensities, electronics does little more than facilitate the work or perh enable one effect to control another. But with modern television techniques impor advances become possible. Perhaps the best known at the moment is the applica of closed circuit television to the teaching of surgery, a method which needs description here (Newton and Atkins, 1952). It does, however, emphasize the imp tance of the television camera as an unbiased observer whose presence does necessarily intrude, and which can be made to operate in very adverse situatio Thus in the technique of rotational x-ray therapy, a simple television camera may used to relay the image of the patient on a fluorescent screen to a viewing tube outs the cubicle. This enables the orientation of the patient relative to the x-ray beam to examined without danger to the operator. The television camera tube as a transdu

is in some respects equal in performance to the human eye, but there is some doubt as to whether even the most sensitive type would be adequate to view a fluorescent screen as used in diagnostic radiology, although one instrument on these lines has been constructed. An alternative method makes use of an image intensifier, which contains a fluorescent screen about five inches in diameter in contact with a photo-electric surface (Teeves and Tol, 1952). Light produced in the screen liberates electrons from the photo-emitter, and these are accelerated through a potential difference of about 25 kilovolts and focussed on another fluorescent screen. Because of the extra energy imparted to the electrons and of the geometry of the optical system the gain in brightness is of the order of 1000. The field of view, however, is small. Apart from any gain in convenience these techniques also make it possible to manipulate the image in almost any desired manner, for example its contrast may be increased or decreased over the whole picture or only part of it.

When the process of screen brightness intensification was first suggested it was thought to have almost limitless possibilities, but it has since been realized by several workers that the increase of observable detail so obtained would be small because of the fluctuating nature of the screen image formed by relatively small numbers of x-ray quanta (Sturm and Morgan, 1949). The gain in convenience, however, would be great as the method would eliminate the need for dark adaptation before screening.

Nuclear physics and medicine

Geiger-Muller counter and scintillation counter

A very extensive and increasing range of electronic apparatus is being used in the application of nuclear physics to medicine (Mayneord, 1950; Pochin, 1951). Detailed consideration of this field is beyond the scope of the present article, but it is appropriate to describe two basic detecting instruments, the Geiger-Muller counter and the scintillation counter, which are of general interest and which also illustrate an important principle in applied electronics.

The function of both is to detect the passage of an ionizing particle by producing from it an electrical pulse which is then counted automatically by electronic circuits. The ionization produced by most particles in a conventional ionization chamber, [illegible]

because of the limitations imposed by electrical noise due to random fluctuations of the electrons in the circuit. If, however, the initial electric charge can be amplified *before* conversion to a voltage, the noise limitations will be largely overcome, and incidentally the apparatus will usually be less complex.

The Geiger counter consists of a sealed tube containing a fine wire anode surrounded by a concentric cylindrical cathode. The tube is filled with a gas mixture at reduced pressure, and a thin window may be set into the tube wall to permit the passage of low energy particles The entry of an ionizing particle into the gas volume produces a number of ions from the gas, and these may be collected by applying a small potential difference between anode and cathode. Since the initial or primary ionization can produce only a very small voltage pulse, the potential difference across the tube is increased to such an extent that primary electrons are accelerated to produce more ionization by collision with gas molecules. An avalanche of ionization corresponding to a very large voltage pulse will be then produced This process is known as gas amplification, and as used in the Geiger counter is an "all or nothing" mechanism, the size of the resultant pulse being independent of the original ionization. It is possible, however, by a careful choice of operating conditions to make the output pulse proportional to the primary effect; this is done in proportional counters and in gas-filled photo-electric cells. It is clear that the Geiger counter is a very much simpler

and cheaper device than the combination of ionization chamber and amplifier which would be necessary to produce the same effect without gas amplification.

In the second method the ionizing particle does not ionize atoms but excites electrons contained in certain crystalline "phosphors" to higher energy states. On regaining their original states the electrons emit light, so that one incident particle will produce one flash of light which may contain many light photons. This light pulse could in principle be converted into a voltage pulse by a photo-electric cell, but as in the simple ionization chamber, we should then find the resulting pulse difficult to distinguish from its background. Instead, use is made of the phenomenon of secondary emission in the photo-multiplier tube. The flash of light ejects photo-electrons from a photo-sensitive cathode, and these in turn are accelerated towards a secondary emitting surface from which each electron ejects an average of four secondary electrons. By using a number of secondary emission stages, multiplication factors of up to 10^9 are achieved without interference from random noise. The output pulse of the photo-multiplier is thus large (up to 50 volts) and proportional to the energy of the original particle. Not only can low energy particles be detected and their energy estimated, but the duration of the light flashes from suitable organic crystals can be as small as 10^{-8} second or less. Some photo-multipliers will amplify such current pulses with little time distortion, and thus it becomes possible to time nuclear events with some accuracy. The scintillation counter is an extremely valuable device the potentialities of which are far from being exhausted (Mayneord, 1953*b*).

Modern forms of the Geiger and scintillation counter have made possible the measurement of radioactive isotopes in amounts far beyond the limits of detection by chemical means. Moreover, since the radiations from many of these elements can be detected outside the system in which they are located, new and powerful methods of investigating metabolic processes in the living subject are now in use. Thus it is possible to investigate thyroid function using no more than 10^{-10} gramme of the radioactive isotope of iodine I-131 and to measure the amounts appearing in the thyroid, the blood and the urine with an accuracy of a few per cent. The administration of such minute amounts, even though usually accompanied by a few microgrammes of the inactive element, is insufficient to interfere with the metabolism of the element in the body, but acts as a tracer giving information about its uptake and its metabolic pathways. It will be sufficient for our purpose to record here that, with a continually increasing field of application, the major uses of tracer methods include the following. Radioactive iodine is used to study not only thyroid function but in [illegible] metastases from thyroid cancer. Blood [illegible] uncertainty than [illegible] ured by observations on the [illegible] elements such as Na24, K42, [illegible] important aspect is the location of tumour tissue by a differential uptake [illegible] radioactive elements, notably P32 and K42. An extremely small Geiger counter having a sensitive volume only 10 millimetres long situated at the end of a 3 millimetre diameter probe is being used both to explore the distribution of K42 in exposed brain [illegible] the accumulation [illegible] al detectors [illegible] onal display [illegible] element in (by mechanical or television methods) of the distribution [illegible] an internal organ such as the thyroid.

Control by electronics

The use of the electrocardiograph to determine the instant of an x-ray exposure has already been mentioned, but there are further possibilities in the use of electronics for control purposes. The reason is twofold. Thermionic valves have no mechanical

moving parts and therefore will operate extremely rapidly and with certainty. They are therefore replacing mechanical switches for many purposes. For example, a recent trend in the design of diagnostic x-ray sets is to eliminate the heavy contactors which can be noisy, slow and troublesome and to replace them by triode switches. Although these developments are in their early stages, they are likely to lead eventually to improved performance and reliability.

Furthermore, electronic valves and circuits, as mentioned above, can perform complex mathematical operations automatically. They may therefore be used to convert information consisting of electrical signals received from the patient into a form suitable for the control function required. Thus if in the example discussed previously an x-ray exposure is desired at some instant *after* the QRS complex of the heart, an electrical delay circuit may be used to add a fixed time interval to the instant determined by the electrocardiograph to close the contactor at a later time.

A notable contribution of electronics to surgery and medicine is the control of devices designed to simulate temporarily the functioning of living organs when the latter are undergoing surgical treatment. An example which is yet in the process of development is the extra-corporeal heart-lung machine (Melrose, 1953). The idea of this machine will be familiar to most readers, but we wish to emphasize the part played by electronics in its control. In the living body, the processes of respiration and blood circulation are under nervous control, their rates being adjusted to satisfy the normal needs of the body. When, however, these functions are performed by machines external to the body, this control factor is lacking, and as it would be very difficult to regulate the electrical equipment adequately *via* nerve action potentials, this nervous control is replaced by an electronic system with its own "sensory nerve endings" or transducers. These transducers respond, for example, to blood pressure and blood level and ensure that the processes continue at something like their correct rate for the limited duration of the operation.

Electronics in therapy

The use of electronics in therapy is in general not a recent development. Perhaps its oldest application is in the production of high frequency alternating currents for tissue heating in diathermy and short-wave therapy. Originally these currents were and often still are produced by the spark generator as used in the first experiments of Hertz and Marconi, but when higher frequencies and larger powers were required, thermionic valve generators came into use. These consist simply of triode valve oscillators with positive feed-back used in conjunction with an oscillatory circuit, the whole serving to convert power from the supply mains into power at the frequency desired. The high frequency currents so obtained are of value because they produce heat in living tissues, either concentrated locally or distributed uniformly over an appreciable volume, without either electrolysis or muscle stimulation.

Before 1940 the highest frequency used in tissue heating was about 50 megacycles per second, but in the early years of the war the development of the cavity magnetron made available high powers at frequencies up to 10,000 megacycles per second. It was at first hoped that these radiations might have specific effects on molecules in living tissue by exciting oscillation in them at their resonant frequencies. No such effects however have yet been confirmed (Roberts and Cook, 1952), and at present the ultra-high-frequency generator seems to afford nothing but a very convenient means of heating localized volumes of tissue.

An important application of electronics in therapy is its use in muscle stimulation. A muscle may require exercise in the conscious patient, or it may be necessary to maintain some body function artificially while the patient is under anaesthesia. In such cases a valve generator is made to produce a waveform of the appropriate shape and this is applied through suitable electrodes to the motor point of the muscle. Such

methods may be used, for example, to maintain the circulation of blood in the leg by stimulation of the gastrocnemius muscle, or to maintain respiration by automatic control of the diaphragm *via* the phrenic nerve.

CONCLUSION

We have tried to show that electronics has provided the clinician with new and powerful methods of observing and in some cases of controlling body function. The full extent of the application of these methods is still to be realized, although clearly there are limits to the ultimate performance of any apparatus. Moreover, there exist practical limitations which need careful consideration if the maximum advantage is to be gained from the use of electronic methods.

Reliability and suitability of design for clinical work must be of first importance in medical apparatus. The reliability of electronic equipment can be of a high order, but is not yet as great as that of simpler physical instruments. Not only are the valves themselves more liable to failure, but the greater complexity of the apparatus increases the probability of faults developing. It is thus desirable to employ simple circuits which, furthermore, are so devised that their performance is as independent as possible of the characteristics of individual components. The design of electronic apparatus calls for restraint and judgment in assessing the conflicting requirements of reliability and complexity. It is also not always well recognized, particularly in technological circles, that the instrument which operates perfectly on the laboratory bench may behave most unpredictably in the operating theatre when connected to a live patient. Every precaution must be taken in the design so that no harm can come to a patient through failure in any part of the apparatus. Its operation should require a minimum of thought on the part of the user whose attention must usually be directed to clinical matters.

Whenever a specialized branch of science is being applied to clinical work, it is becoming apparent that co-operation is required between the clinician and a specialist in that science. In the case of electronics it would appear that the best course lies in collaboration between the clinician and a physicist who has both first-hand knowledge of electronic techniques and experience of the application of physics to medical problems. The physicist can then co-operate from the beginning in the solution of the problem, a course which is likely to ensure the best utilization of available methods. Assisted by technicians, he can not only develop the apparatus required, but can assist the clinician both in its mode of use and in the equally important problem of assessing the physical significance of the records.

REFERENCES

TUMOURS OF THE GLOMUS JUGULARE OR TYMPANIC BODY

By F. C. W CAPPS, F.R C.S.
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DEFINITION

For many years cases of very vascular tumours of the external auditory meatus, middle ear and surrounding structures have been reported from time to time in the literature They have usually been designated angiomas or haemangio-endotheliomas, and while there has been much speculation as to their particular site of origin, little was forthcoming about their aetiology or the type of tissue from which they might arise. Since the establishment by Guild (1941) of a body in the adventitia of the jugular bulb or on branches of the ninth or tenth nerves in the middle ear which was analogous to the carotid body, and the report of a case by Rosenwasser (1945) of a "carotid body like" tumour in the middle ear, it has become recognized that most of the above tumours have arisen from the glomus jugulare of Guild, now called by some the tympanic body.

HISTORICAL

As early as 1840 Valentin described a formation resembling a ganglion on the tympanic nerve and suggested calling it the gangliolum tympanicum Krause, in 1878, demonstrated that this structure was not a ganglion, but a vascular formation lying between the perineurium and the periosteum in the initial part of the canaliculus tympanicus. As this structure resembled histologically the carotid gland or body he suggested the name glandula tympanica In 1932 Watzka, on somewhat limited material, stated emphatically that the structures did not exist and nothing more was heard of them until Guild's independent discovery already quoted.

From 1945 onwards several workers in America and Canada (Rosenwasser, 1945; Le Compte, Sommers and Lathrop, 1947, Kipkie, 1947) described tumours of a carotid body like nature arising in the middle ear, and an association with the glomus jugulare of Guild was suspected. Probably the first clear case of a "carotid body tumour" in the middle ear was that reported by Lubbers of Amsterdam in 1937. This was associated with a jugular foramen paralysis syndrome and with a typical carotid body tumour in the usual site on the other side; the tumour in the middle ear was thought to be metastatic from the carotid body and its true origin was not suspected at the time

AETIOLOGY

These tumours occur most often in adults of middle age but have been reported in cases as young as 18 years and as old as 80 years. They appear five times more often in women than men. This is in contrast to carotid body tumours which in a series reported by Sonck (1937) (quoted by Berg) affected 110 women to 96 men.

Bartels (1949) mentions three different families in which the tumour has occurred in a number of their members, the most striking being one in which it occurred in three generations

Geokoop (1932) also reported three cases of fibro-haemangioma of the petrous bone and middle ear in three sisters All of them had a facial palsy.

There is no evidence that infection or injury predisposes to the onset.

These tumours have also been described as non-chromaffin para-gangliomas of the middle ear (Lattes and Walter, 1949; Dockerty, Love and Patton, 1951) or as tympanic body tumours (Lundgren, 1949; Berg, 1950). The former are so described to distinguish their structures of origin from the chromaffin tissue or para-ganglia chiefly represented by the adrenal bodies.

Lattes tabulates the differences as follows:

NON-CHROMAFFIN AND CHROMAFFIN TISSUE PARA-GANGLIOMAS

Chromaffin tissue or para-ganglioma	*Non-chromaffin para-ganglioma*
[illegible]	Direct association with cranial nerves and their ganglia and vessels of the branchial arches
Secretion of epinephrine or similar substance	Histologically similar if not identical with each other and consist of nests of epithelial cells in [illegible]
	Secrete no hormone
	Probably chemoreceptors
	Tumours arise from them

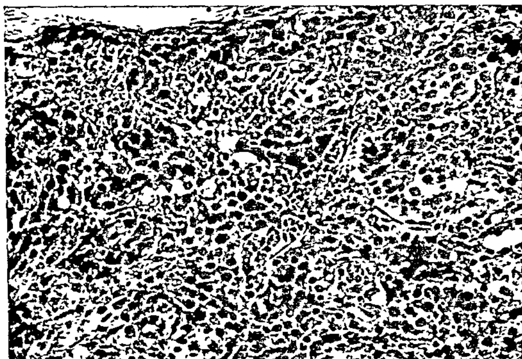
As chemoreceptors the same factor may bring about malignant change in several of them at the same time. This would account for the several reports of a carotid body tumour on one side associated with a glomus jugulare tumour on the other.

SURGICAL ANATOMY

Guild states "Human temporal bone sections reveal structures, in several respects like the carotid body, for which the name glomus jugularis is proposed. Usually they are in the adventitia of the dome of the jugular bulb, immediately below the bony floor of the middle ear and near the ramus tympanicus of the glossopharyngeal nerve. Usually there is but a single flattened ovoid glomus, about 0·5 millimetre in the longer diameters and about 0 25 millimetre thick. Occasionally about two or more smaller bodies are present, sometimes one or all are in the canal that transmits the ramus tympanicus through the floor of the middle ear (in one case also along the course of this nerve over the cochlear promontory).

"Each glomus, wherever located, consists of blood vessels of capillary calibre with numerous epitheloid cells between the vessels. Usually, but not always, the vessels are the more prominent feature. Innervation and blood come from the same trunks that supply the carotid; namely. glossopharyngeal nerve and ascending pharyngeal artery (through its inferior tympanic branch).

"This structure has as yet been studied only in 24 sections of decalcified material stained with Ehrlich's hematoxylin and eosin, and has not been sought for in forms other than man. Presumably it has functions like the carotid body, perhaps limited to a smaller circulatory region. Suggestion: similar structures may be present along other parts of the peripheral circulatory system." And later "the main points of clinical and of surgical interest that have been revealed by the additional study of normal material since the first report, in 1941, of the glomus jugulare, are: (i) that these structures occur not only along the nerve of Jacobson (tympanic branch of the glossopharyngeal) but also, and about as frequently, along the course of the nerve of Arnold (auricular branch of the vagus); (ii) that slightly more than half of them are in the adventitia of the dome of the jugular bulb; (iii) that along the nerve of Jacobson a glomus formation may be present, distal to its promontorial part, in the region where the nerve becomes continuous with the lesser superficial petrosal nerve near the geniculate ganglion of the seventh; (iv) that along the nerve of Arnold a glomus formation may be present at least as far distally as where the mastoid



(*a*)

(By courtesy of Dr Stacy R Guild, and "Cancer")



(*b*)

FIG 40.—(*a*) Photomicrograph of a normal glomus jugularis; (*b*) temporal bone. The arrow indicates a mass of paraganglionic tissue (glomus jugulare) in the adventitia of the jugular bulb, near the floor of the middle ear JB=jugular bulb, ME=middle ear.

(By courtesy of Lattes and Waltner and "Cancer")

canaliculus crosses the descending part of the facial canal; and (v) that the observed 'normal' variation in location of glomus formations is sufficient, in case tumours arise from them, to account for all the differences in order of symptoms that have been reported for patients with glomus jugulare tumours, also for the differences in apparent 'origin' that have been found at operations to remove such tumours."

PATHOLOGY

The gross appearance of the tumours is not typical in any way (Fig. 40*a* and *b*). When found casually in the external auditory meatus they have usually been interpreted as aural polypi secondary to middle ear disease. Their extreme vascularity on removal had, however, led to their histological examination. They show a remarkable tendency to reproduce the architecture of the normal body described by Guild and of the carotid body. They are made up of nests of "chief" or epitheloid cells, fairly uniform in size and surrounded by vascular stroma. Capillaries are present in the fibrous septa between the cell nests. Variation in size and shape of the chief cells is likely to be more marked than in the normal organ. Well-formed, fairly large cells with good blood vessels suggest a benign type. Rather more growth activity is suggested by smaller cells with darker nuclei and most activity is suggested by great variation in cell size with darker nuclei. It is unusual to see mitoses even in the most actively growing types. The fundamental pattern is best brought out by silver impregnation of the reticulum. Le Compte divides them into three groups: (1) The usual, which reproduces the normal structure faithfully; (2) the adenoma-like type; (3) the angioma-like type in which the chief cells have a spindle or crescent shape simulating endothelial cells. It is doubtful if they ever give a chromaffin reaction and nerve fibres are rarely demonstrable. In poorly preserved specimens the epitheloid cells may become



Fig 41.—Superficial area of a glomus jugulare polyp, showing granulation tissue and few epitheloid cells.

inconspicuous from shrinking of cytoplasm and pyknosis of the nuclei, when erroneous diagnosis of vascular tumour or inflammatory granulation tissue may be made.

Another source of error is in submitting a superficial portion of the aural polyp for diagnosis as a biopsy, in some tumours the more superficial parts may show only granulation tissue in which there are few or none of the typical epitheloid cells (Fig. 41).

The vast majority of these tumours show no tendency to metastasize However, Winship, Klopp, and Jenkins (1948) reported a case of metastasis in a lymph gland and Lattes and Walter (1949) one of a deposit in the liver. Bronzini (1930) reported multiple metastases in the lymph glands of a haemangio-endothelioma. Most of the reported terminations, however, have been post-operative or due to intracranial extension. A case reported by Henson with secondaries in the liver, lung and spleen was found to have spread by the blood stream owing to invasion of the lumen of the jugular vein. This possibility is also suggested by Tamari, MacMahon and Bergendahl (1951).

CLINICAL PICTURE

Many of the reported cases have had a very long history of minor symptoms before they were identified, and, in most cases, it is obviously a very slow-growing tumour and constitutes no early danger to life. They appear to fall into two groups.

The first group are those which arise in the tympanic cavity and pass through the drumhead to form meatal polypoid tumours. These are usually devoid of nerve involvement, and give rise to typically aural symptoms such as pulsing tinnitus, deafness, often associated with pain, and vertigo. Local removal is complicated by severe bleeding and likely to be followed by recurrence.

The second group consists of those which arise in the neighbourhood of the jugular bulb, and which find an easy line of spread on the under-surface of the petrous, often with bone destruction and involve structures in the jugular foramen (ninth, tenth and eleventh cranial nerves) anterior condylar foramen (twelfth nerve), and *via* the foramen lacerum anterior to the middle fossa of the skull (fifth and sixth nerves). Such widespread tumours sooner or later invade the tympanum through its floor and involve the seventh nerve and labyrinth Many of these cases are only recognized after the nerve palsies are well advanced and often symptoms related to the ear itself are late. An increasing number have been found to have reached the neuro-surgeons with symptoms of posterior fossa involvement

The following case histories are illustrative. Cases I–III report on cases arising within the first group category and cases IV–VII fall within the second group.

CASE I 1942. 49 *years Female.*

History—Deaf for years on left Under otological observation on and off for 12 years. A diagnosis was not made. The patient's husband (a doctor) described an apparent red swelling showing through the drum for some time, and about 6 months before she was seen by me, a swelling in the meatus which he thought was a boil

O.E.—Severe conduction deafness left. A reddish polypoid swelling filled the inner part of the meatus surrounded by debris Pain referred above and in front of ear X-ray examination showed a cellular mastoid on the right and a sclerosed mastoid on the left with a doubtful area above the attic.

Diagnosis—Chronic suppuration with cholesteatoma and polypus.

Operation (11 2 42)—A cellular mastoid The lateral sinus was far forward and the antrum was deep seated but appeared normal Copious bleeding occurred from meatus and tympanic area No evidence of cholesteatoma Polypoid mass and its pedicle were removed; the latter appeared to be attached somewhere near the eustachian tube. No ossicles. Bleeding controlled by B I.P P. pack through meatus Mastoid cavity filled with muscle graft and wound closed. Pack removed in one week. Recovery uneventful.

Histology.—Polypus reported by Professor G. Hadfield as haemangio-endothelioma (Fig. 42).



Fig 42—Section of polypoid tumour (*from Case I*). A poorly preserved specimen showing the shrinking of cytoplasm and pyknosis of nuclei described by Le Compte.

11.3.42 20 milligrams 2 centimetres 1 millimetre platinum filter radium tube applied to several fields. Total area 300 r.

Followed at regular intervals for 7 years, always needed toilet and cavity failed to epithelialize. Small area of dead bone on floor of meatus.

Section submitted to Mr Winship (1948) and diagnosis of glomus jugulare tumour established The stroma not extremely cellular but very vascular. Probably some oedema and not much evidence of tumour activity

February, 1949. A very noticeable blue soft swelling in tympanic area. Still dead bone on floor of meatus.



Fig 43.—Tumour structure still present on promontory after 10 years and following radical mastoidectomy and irradiation (*Case I*)

93.49.–6.4 49. Deep x-ray therapy 1,000 kV. 5,000 roentgen twice daily in 29 days. There was an immediate shrinking of the blue swelling but this did not completely disappear for over a year (May, 1950).

May, 1951. A small sequestrum from the floor of the meatus separated and came away.

December, 1951 A small area of dead bone was still present but the whole cavity is now clean and epithelialized and the tympanic area appears completely free of all tumour.

After a further year she became very giddy and had a positive fistula sign. Spread of sequestration was suspected and the cavity was revised under a dissecting microscope. A thin felt of growth covering the inner tympanic wall was removed by morcellement and erosion of the promontory and footplate of the stapes were clearly seen. Six months later she was well and free from vertigo and the cavity was dry This patient's history went back more than 12 years before she was seen by me, so that she is alive and well after at least 23 years without any very radical surgery, but the possibility of further recrudescence is present (Fig 43).



Fig 44—Section of polypoid growth (*from Case II*) Not of active type

CASE II 1944 51 *years Female*

History—First seen 21 4 44 A long history of chronic suppurative otitis media (right), with increasing deafness. Recent severe pain in right ear. On examination there was a polypus presenting at the right meatal entrance, with a thin purulent discharge; tenderness over the mastoid and definite but slight right facial weakness. No other evidence of intracranial involvement No useful hearing in the right ear.

Treatment.—Exploration of the mastoid performed The cortex was hard and sclerosed; there was pus under pressure in a pre-sinus group of cells. The bridge was removed, followed immediately by extremely free bleeding from the tympanic cavity. The radical operation was completed with difficulty The bleeding arose from the pedicle of the polypus which was removed, and its attachment was seen to be the inner tympanic wall. An adrenaline pack failed to stop the bleeding A posterior flap with base uppermost was cut and stitched up to the temporal fascia and the cavity packed with B.I.P.P. gauze.

Histology.—The polypus was reported by Professor G. Hadfield as haemangio-endothelioma (Fig 44)

The section was submitted in 1948 to Winship and the diagnosis of glomus jugulare tumour was established "Growth does not appear to be very active"

Progress—Post-operatively there was increased facial paralysis, although never complete, and after 4 weeks there was complete recovery

16.12.44. Cavity dry and well epithelialized but there was some engorgement in the tympanic area. The labyrinth responded to cold caloric tests Over the next 4 years the veins in the tympanic area definitely became more prominent.

21.5 49. A very definite recurrence of a blue cystic swelling, and a leash of engorged vessels in the attic area. Patient began to get severe bouts of vertigo.

December, 1951. Deep x-irradiation cavity. 250 kV. A minimum of 3,000 r. a maximum of 3,400 r.

January, 1952. All engorgement of vessels has disappeared and the swelling is alrea smaller.

December, 1953. Cavity is flat and although a little unsteady at times the patient lea a useful life and can play golf. The tumour was for 10 years under personal observati and must have existed for an unspecified period of probably many years before.

CASE III 1925. 37 *years Female.*

History.—An old patient of the Throat Department over a long period of time, wi a sore mouth and throat and recurrent dysphagia. Nothing definite was ever found. I November, 1948, she complained of pain in the right ear. [illegible] glomus jugulare tumour. There was marke deafness in the right side which was of *perception* type, and Weber's test was referred t the left. The patient complained of severe tinnitus in the right ear.

Treatment.—August, 1949, paracentesis performed of the drumhead, and biopsy take of the vascular tumour of the *middle ear.* Typical glomus jugulare tumour formation very cellular, without much in the way of *formed vessels*, and "may be a very active neoplasm" (Fig. 45).

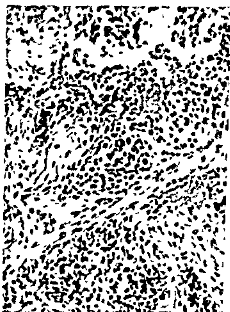


FIG 45.—(*Case III*) Early case of active type tumour still confined to middle ear

November, 1949. Trans-mastoid exploration of the middle ear and area of jugular bulb. Facial nerve exposed and freed and drawn out of the way. Lateral sinus packed off and internal jugular vein tied high up. There was free bleeding at all stages of the operation which made it extremely difficult. Tissue was removed from the floor of the tympanic cavity, and after removal of the floor, from the upper surface of the jugular bulb Sections of both these tissues showed typical glomus jugulare tumour. As it was found impossible to remove the bulb of the vein, the area was cauterized with diathermy. Twitching of the shoulder was noted during the proceeding

She had a post-operative facial paralysis and there was considerable mental disturbance with a positive Kernig sign. Large doses of penicillin were given and the patient ultimately made a full recovery. She was found to have a paralysis of the right vocal cord, and the right eleventh cranial nerve also was affected

Progress.—December, 1951. The facial paralysis has recovered with subsequent spasm of that side of the face Movement of the shoulder has recovered. The right vocal cord





Plate I.—Appearances on otoscopy of case III That on the right shows definition of the tumour when the drumhead was compressed with a Siegle's speculum.

(By courtesy of "The Journal of Laryngology and Otology")



Plate II.—Appearances seen in the external auditory meatus of case IV

(By courtesy of "The Journal of Laryngology and Otology")

still remains paralysed. There is no evidence of any recurrence in the mastoid area which is well epithelialized.

December, 1953. Still no sign of recurrence.

CASE IV. 1951. 18 *years Female.*

History.—7.2.51 Four years husky voice which persisted, with occasional temporary improvement

Two years tinnitus in the left ear, followed 6 months later by deafness in the left ear which progressed and became complete. One year left facial palsy Eleven months diplopia

O E—Complete paralysis of the left sixth, seventh, ninth, eleventh and twelfth cranial nerves Also total deafness in the left ear, and inactive left labyrinth. Left vocal cord in cadaveric position On otoscopy, a bright red tumour was seen arising from the floor of the middle ear, bulging the lower part of the drum and spreading along the floor of the meatus (Plate II).

X-ray examination showed considerable destruction of the petrous bone on the left side and enlargement of the jugular foramen

Biopsy proved the tumour to be extremely vascular



FIG. 46—(*Case IV*) Section from a growth with wide nerve implication In addition to vascular spaces, there is marked cellular pleomorphism which indicates the probable malignancy of the neoplasm

Histologist's report—Typical glomus jugulare tumour Slide shows a lot of cellular aberration, with large nuclei, which would suggest great growth activity (Fig 46).

Treatment—X-ray therapy 1,000 kV from 7 3 51 to 13 4 51 of 4,000 r. in 36 days. Two weeks after treatment the tumour in the middle ear had regressed.

Subsequent progress—Immediate definite improvement of the left sixth nerve lesion. Facial movements also improved Definite increase in power of the left shoulder; palate, pharynx, tongue, larynx as before

All the nerves appear to have recovered completely (1953), the seventh with some spasm, but the left cord has remained fixed probably from long disuse. The girl is well and at full work. Radiographs show bony changes to have remained stationary (Fig. 47).





FIG 47—(*Case IV*). X-rays of petrous processes to show great destruction on left side which remained unchanged 2 years after irradiation.

CASE V 1929. 52 *years Female*

History.—An old patient of St Bartholomew's Hospital, first seen in 1929 by Mr. Sydney Scott Diagnosis: otosclerosis, right ear

In 1935 complained of acute pain in the left ear Drumhead seemed to be red and full Paracentesis performed blood only, no pus. This was followed by continuous granulations arising from the drumhead

In 1937 Mr Scott's note states: "Firm pulsatile bright red swelling in the middle ear on the left side with no otorrhoea " Considered to be an angioma, and admitted for removal.

Biopsy—Showed a haemangio-endothelioma This was removed by diathermy through

1948 to Mr Winship and diagnosis of glomus

very similar to Case II (Fig. 48).

Mr Scott's note, December, 1938 "No visible

4.6.45 Recurrence of the tumour in the left meatus. Bled profusely on probing Had left facial weakness for 12 months. Also weakness of the left palate and left tongue and left laryngoplegia present

Treatment.—Full dose of deep x-rays, 200 kV 3,000 r in 20 days.

Progress—21 10 46 Atresia of the left external meatus but no signs of recurrence.

16.4 48. Still paralysis of the left face and left vocal cord; tongue and palate better. Meatus dry and healed

Now very deaf indeed. Hears with a valve hearing aid but will not tolerate it.

Died 5.4.50. In St. Matthew's Hospital Broncho-pneumonia, cerebral thrombosis, arteriosclerosis. No *post mortem* When last seen at St. Bartholomew's Hospital, no evidence of any recurrence in the middle ear, and nothing to suggest deeper involvement by growth.

CASE VI.

kindly referred for treatment by Mr. J. F. Simpson of St Mary's

Mr Colledge

ma

Review of the section 1952 showed it to be a g ths and nothing was heard of him for 7 years because, as he put it, "he had had no pain". His appearance followed a severe haemorrhage from the post-aural wound from which he had occasional bleeding for 5 years He had had weakness of right face and tongue for

4 years and had become increasingly deaf. He had total perceptive deafness, recurrent nerve palsy, seventh and twelfth nerves paralysed X-ray examination showed almost complete destruction of right petrous. There was a swelling strongly suggestive of carotid body tumour on the opposite side (Fig 49). A soft pulsating swelling with a thrill and bruit involved the post-aural scar and filled the mastoid cavity. Suspecting an arterio-venous aneurysm Simpson ligated the external carotid, posterior auricular and occipital arteries. Haemorrhage caused the greatest difficulty and there was little improvement. An attempted biopsy of the carotid swelling was reported as a lymph node He was then treated with x-irradiation (8,000 r by 1,000 kV machine) At the same time a single test dose of 500 r was given to the carotid swelling Had it been lymphoid tissue regression might have been expected There was no change and it was thought therefore to be a carotid body tumour As a result of treatment he became very lethargic, and hypopituitarism as a result of oedema was suspected This improved spontaneously when the use of ACTH was being considered His already existent anaemia increased June, 1953, after the reaction ended his headaches and tinnitus decreased, bleeding ceased, and the swelling became a blue scar behind and a hard fibrous mass in the cavity. The original paralyses persisted and he developed some contra-lateral anaesthesiae suggestive of mid-brain involvement When seen in December, 1953, further irradiation could not be considered; some areas of growth at least were controlled and his life was more tolerable. He is at work on and off

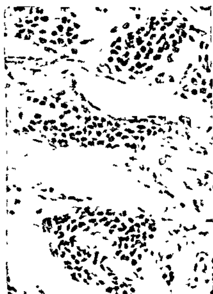


FIG 48 (*above*) —(*Case V*) Histology very similar to that of *Case II*

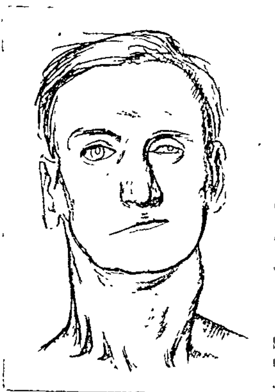


FIG 49 (*right*) —(*Case VI*) Associated glomus jugulare tumour on right side, with nerve palsies, with a carotid body tumour of left side

CASE VII

A lady of 47
hospital and it
ceruminous gla
radical mastoid
pital for nervo
two rounded red swellings in the tympanic area, the upper one lying over the facial nerve Biopsy showed typical glomus jugulare tumour. Radiography showed erosion of the petrous and the caloric response on the right was much diminished and there was no useful hearing She was found to have fixed right vocal cord On going into her history

further, she was said to have had an emotional shock in Brussels in 1943 ("not unconnected with the activities of the Gestapo"), she partly lost her voice and had "a strong over-balancing feeling in the blackout". Both conditions improved fairly rapidly. Obviously her petrous and labyrinth were involved at that time, but it was 6 years before she developed her polypus and a further 4 years before the recurrence in her mastoid cavity.

She has been treated by x-irradiation with almost immediate regression of the swellings. She still gets occasional facial twitching (December, 1953) The right vocal cord remains fixed.

Additional clinical observations

Quite severe vertigo has accompanied recurrence in the tympanic area of mastoidectomized patients. In many cases caloric testing of the labyrinth gives a negative reaction, but in as many others it appears to be still positive.

Mattick and Burke (1952) report a case of pulsatile swelling around the ear very similar to the sixth case which was thought at first to be an arteriovenous aneurysm. Histology had at first suggested a malignant tumour, but it was later found to be a true glomus jugulare growth.

Examples which came to the neuro-surgeons as cases of brain tumour have been reported by Poppen and Riemenschneider (1951), Dockerty, Love and Patton (1951), and Alexander, Beamer and Williams (1951), and an interesting series is reported from the Neurological Department of the London Hospital by Henson, Crawford and Cavanagh (1953).

Most of the cases found in the literature up to 1952 are recorded by Winship, Godwin and Creveld (1952); since then also series by Cova, Meda and Nicelli (1952), Capps, Munro Black and Magarey (1952), and Salkeld and Ballantyne (1953).

DIAGNOSIS

Aids to diagnosis

X-ray pictures (preferably stereoscopic) of the petrous bone give valuable information of the degree of local spread, and are essential in the follow-up of cases in which operation has been performed on meatal or tympanic tumours, and if irradiation treatment has been given.

The only certain confirmation is histological. This is an easy matter when a polypus has been removed, but there is still no objection to doing it in case of meatal spread, or by exploring through the tympanic membrane when a middle-ear tumour is suspected but has not yet perforated the drumhead. A pack left in for 24–48 hours readily controls the haemorrhage.

Differential diagnosis

The commonest mistake in the early cases which may show a bulging red drum membrane is to diagnose acute otitis media. Polypoid tumours in the meatus are usually thought to be granulomatous polypi secondary to chronic otitis media. Those on the under-surface of the petrous and invading the posterior and middle-cranial fossae cannot be differentiated from other tumours at the base of the skull until the characteristic appearance in the middle ear is manifest.

PROGNOSIS

In 1952 Winship, Godwin and Creveld gave a mortality for their series of 21·5 per cent. Most of these deaths, however, were due to operative measures or occurred because the tumours were too far advanced for any treatment to be of avail. Several of the survivors were known to have persistent disease.

Earlier recognition and appropriate treatment should reduce this mortality rate, and the results in the author's cases and in others known to him show a much more favourable picture.

TREATMENT

Surgical treatment

Because of the great vascularity of the tumours surgery is always difficult and in the second group may be fraught with great danger to cranial nerves and vital structures, and of necessity removal will be incomplete. The following points are based on the experience gained by the author.

(1) That since carotid and tympanic body tumours are both histologically benign and slow growing (case histories of 20 years are common), haste in treatment is not imperative, and many cases can be watched for a long time.

(2) Surgical removal should be limited to the first group tumours. Simple removal of the polypus is usually followed by recurrence, and therefore a radical tympano-mastoidectomy is preferable as giving more thorough removal and a cavity in which any recurrence is not under pressure of confinement and is more easily observed and dealt with, either by surgery or radiotherapy. Bleeding is not usually severe until the tympanum is reached and in a bony cavity haemorrhage is readily controlled by packing.

(3) In Group 2 tumours some method must be found to destroy, sterilize, inhibit or shrink the tumour and to relieve the pressure on the nerves without the need to attempt surgical extirpation. Angiomatous tumours in more accessible areas may be dealt with by the injection of sclerosing fluid such as hypertonic saline solution or boiling water, but this would be difficult at the base of the skull.

The ligation of large vessels in the neighbourhood (external carotid artery, internal jugular vein) with occlusion of the lateral sinus is likely to give but limited and temporary effect as collateral circulation is so rapidly established.

Chemotherapy

It has been suggested that the high incidence in women might indicate possibilities for hormone therapy, though as these chemoreceptors appear to influence the chemistry of respiration and not to be connected in any way with sex organs, this would appear unlikely.

Any oozing at the end of the operation has been controlled by gauze-packing impregnated with B.I.P.P This can be left in from 1 to 2 weeks with perfect safety and seems to inhibit any infection. When removed, all oozing is found to have ceased and we have had no recurrent haemorrhage. Avomine 50 milligrams three times daily or Dramamine can be given to control any post-operative vertigo (Cawthorne, 1953).

Anaesthesia

We have not used controlled hypotension during the anaesthesia of any of our operations, but when an anaesthetist skilled in this procedure is available and the condition of the patient warrants it, hypotension should have obvious advantages.

Radiotherapy

Some form of radiotherapy with its accuracy of field and penetration would obviously be a happy solution, and does indeed give quite lasting improvement. It is true that it appears to have but little effect on the analogous carotid body tumours which, by nature of their situation are more easily observed In one such coincident *tumour previously mentioned in the author's care (Case VI)*, a minimal dose of 500 r. was given to the carotid body swelling as some doubt [illegible]
lym [illegible]
afte [illegible]
bod [illegible]
the [illegible]
neurological disturbance. A very slow-growing and histologically benign tumour still further inhibited by radiotherapy is probably better left *in situ*.

Shrinkage of the tumour is probably brought about by thrombosis of the vessels as was shown by the histology of a *typical* recurrent polypus 1 month after it had received 4,500 r. at 1,000 kV. The destructive effect on the main bulk of this polypus was disappointing, and it is considered that radiotherapy should only be given after the polypus has been removed or a tympano-mastoidectomy performed (Fig. 50).

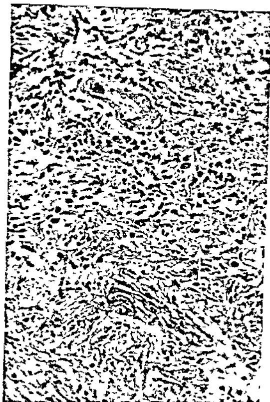


FIG 50—Section of polypus which has been irradiated to show that cell structure is not destroyed, but blood vessels (indicated by arrows) are thrombosed

In one case (Case III), the earliest seen, with a pink tumour seen through the drumhead and complaining only of deafness, tinnitus and discomfort and with no nerve involvement, the author adopted the radical operation advocated by Lundgren, with exposure and destruction of the jugular bulb. It was a formidable procedure with a very stormy aftermath and subsequent paralysis of the seventh, ninth, tenth, and eleventh nerves. These all recovered, but it is considered that the same result and a happier sequel could have been accomplished with a tympano-mastoidectomy.

Cases of recurrence in tympano-mastoidectomy cavities have been controlled by deep x-ray therapy, and in two such cases the time from the initial mastoid operation until the treatment of recurrence by radiotherapy and the subsequent observation has exceeded 10 years, and in both there was nearly 10 years' history before operation.

Radiotherapy in the author's cases has been in the hands of Dr. I. G. Williams but clinical control and responsibility have been shared. He states: "The entire volume of tissue to be irradiated is determined Then with the help of isodose charts fields are planned to cover this region and to deliver a dose of between 4,000 and 6,000 r. in 6 weeks. In most of our cases we have had to stop at about 4,500 r. owing to the local reactions being maximal."

Henson states: "Our own experience and that of others (Dockerty and others, 1951; Poppen and Riemenschneider, 1951) leads us to suppose that radical surgery has no present place in the treatment of these cases. The situation and vascularity of the tumours render any surgical approach extremely hazardous. Semmes (1951) stated that he had one patient in whom complete removal of the intracranial part of a glomus jugulare tumour was achieved 'as far as could be determined'. This is the only

recorded example of survival after radical extirpation that we have traced. Sub-occipital decompression may well be of value when cerebellar or bulbar compression is present. Ligation of the external carotid artery may be helpful in suppressing a troublesome bruit. . . . Our own experience (of radiotherapy) has been satisfactory to date."

RESULTS OF TREATMENT

Personal experience of 9 cases which have been wholly or partly under the author's care may be summarized as follows.

Five presented initially as polypi Three of these had a primary tympano-mastoidectomy and all showed evidence of tympanic recurrence in 5-10 years. One showed evidence of involvement of the tenth nerve which had probably remained unrecognized from the onset The remaining 2 had removal of the polypi. One had recurred twice and the other had obviously a persisting tumour in the middle ear. A tympano-mastoidectomy was performed on the latter for pressure symptoms, revealing a curious encysted collection of fluid behind the lateral sinus, possibly changed blood which had leaked back into the mastoid cells when the polypus was removed.

All the recurrences were treated by x-irradiation including the recurrent polypus. The result in the latter was disappointing although some regression took place. Results in 3 cases were good but in 1 case additional, very local, surgical removal was also necessary In the fifth case the tympano-mastoidectomy is only recent and it is proposed to treat the persisting tympanic tumour with x-irradiation. In 3 of these cases the history goes back for over 20 years and in only 1 patient is it apparently as short as 10 years.

The early tumour reported as Case 3 needs no further comment. Surgery was, in my opinion, too radical and the patient nearly died; there has, however, been no recurrence after 5 years.

The remaining 3 cases were all in an advanced stage of subpetrosal spread and cranial nerve involvement when first seen. X-irradiation was given with local regression of the tumour and recovery of most of the nerve palsies in two instances. One has since died but at the age of 70 years, and not apparently from the ear tumour, after a total history of some 15 years. The third case was chiefly bothered by haemorrhage from the local swelling This has completely stopped with fibrosis of the mass but nerve palsies persist.

I have also been fortunate in seeing the results in 3 other cases not under my care. The first a nurse under the care of Mr. Monkhouse and 2 others seen in conjunction with Mr. Ranger.

A nurse under the care of Mr Monkhouse had a meatal tumour This was x-irradiated for 5 weeks at 200 kV and he later explored the mastoid and tympanum, removing tumour until the facial nerve was exposed Four years later "the cavity in the ear has filled up almost to the surface and healed over with normal-looking skin. She has no symptoms other than deafness and a 'shushing' noise which has always been present".

A woman of 54 years, seen in 1952, had had deafness 3 years and dysphagia for 3 months Deafness was complete and there were palsies of the left vocal cord, palate and trapezius She showed nystagmus to the left and a reddish pink mass deep to the membrane. A biopsy was performed through the membrane X-irradiation was given (3,800 r in 34 days at 250 kV) In March, 1953, the membrane was intact with one or two small vessels; the tumour was apparently destroyed The patient is still deaf and the vocal cord still fixed, probably as already suspected in other cases (3, 4, 5, 6 and 7) due to disuse fixation. Palate and trapezius recovered

A woman age 59 years, seen in May, 1952, had had a right facial palsy of 1 year's duration, a pumping sensation in the ear for a period of 2 years and 6 months, giddiness and tendency to fall to the right. She was not "deaf" There was a pink flush of the lower posterior quadrant of the drumhead Valsalva positive Hearing: high tone loss equal on

both sides, and depressed caloric function on the right side. A right radical mastoidectomy was performed and a vascular tumour was found to have exposed the seventh nerve. Biopsy confirmed a glomus tumour. Further treatment by x-irradiation (5,000 r. in 29 days 250 kV.). Facial palsy has persisted but vertigo has ceased and cavity looks well.

It would seem that although we cannot ensure destruction of this tumour, we can, by judicious operation, radiation therapy, or a combination of the two, keep these cases under control. Early recognition and regular surveillance should improve the outlook.

(*See also British Surgical Practice*. Angioma, Vol 1, page 264; Glomus tumours, Vol. 4, page 326.

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SPEECH AFTER LARYNGECTOMY

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Removal of the larynx is essential in many cases of malignant disease. Restoration of normal swallowing is attained by repair of the pharynx, but restoration of the voice presents considerable difficulty.

To understand the mechanism of speech without a larynx it is desirable to consider briefly the normal method of phonation and articulation.

NORMAL MECHANISM OF VOICED SPEECH

The vocal apparatus consists of four parts. The lungs act as *bellows* under the control of the diaphragm and expansible ribs. A current of air can be expelled passively by elasticity of the lungs, or actively by contraction of certain abdominal and thoracic muscles.

The *reed* of wind instruments is represented by the larynx. The aperture of the glottis can be altered in size by contraction of the sphincteric group of muscles, opposed by the dilator group. Contraction of the thyro-arytenoid muscles bounding the glottis can be so regulated as to alter the elasticity of the margins When moderately contracted, these muscles allow the glottic margins to be blown apart and to recoil by virtue of their elasticity, when powerfully contracted, the recoil is more rapid.

The air stream in the trachea escapes in a series of puffs, at a rate commensurate with the elasticity of the glottic boundaries, mild contraction of the muscles breaks the column of air into recurrent puffs of slow rate, while strong contraction causes the air to escape at a rapidly interrupted rate. The vibrating column of air produces mixed sounds of varying pitch, and the force of escaping air alters the amplitude of vibration and increases the volume.

The human reed is obviously different from that of most wind instruments.

The *resonators* are represented partly by the lungs, below the reed and mainly by the pharynx, mouth, nasopharynx and nasal cavities above. Alterations in the size and shape of all except the last determines the quality of the sound, by amplifying certain pitches in preference to others, they also serve as amplifiers in a manner similar to the horn of an old-fashioned gramophone.

The *stops*, which interrupt escaping sounds so as to produce consonants, are the tongue, the isthmus of the nasopharynx, the teeth and the lips.

It is obvious that removal of the larynx, with repair of the pharynx, removes the reed and disconnects the bellows, but leaves intact the [illegible]
and nasal [illegible]

To restc [illegible]
air current and a reed

Whispering

The mechanism of the whisper is similar to that of voiced speech as regards the escaping column of air and the resonators, but differs in that the glottic margins do not vibrate. The current of air is interrupted at the partially closed glottis; its escape through a narrow aperture produces a fricative noise, that is, a mixture of sounds with no predominant fundamental.

A fricative noise can be used in certain methods of whispered speech after laryngectomy.

HISTORICAL

Speech after laryngectomy is no new development. A patient of Dr. S. Solis Cohen in 1895 is reported to have taught himself to speak so successfully that he had no difficulty in making himself heard in a large room (Thomson and Colledge, 1930). Professor Burger of Amsterdam many years ago presented a patient in London, with the ability to speak very well (Burger and Kaiser, 1925).





Fi [illegible] of two patients after [illegible] with belching

OESOPHAGEAL SPEECH

Th[illegible] employs the oesophagus as [illegible]d. a r[illegible]ry [illegible]is expansion of the thorax and by reduction [illegible]

bellows action would tend to draw air into the readily dilatable oesophagus, were it not for contraction of the cricopharyngeal sphincter, a specialized band of muscle at the junction of pharynx and oesophagus.

It is difficult for the normal subject to cause air to pass through this protective sphincter; babies frequently swallow air and so do some air-sucking horses, but with deleterious effects in both instances.

In Arab races a sign of appreciation of a good meal is the taking of air into the gullet, with belching during its escape, but this faculty is difficult to acquire by the normal individual

The operation of laryngectomy detaches the cricopharyngeal sphincter from its origin on the cricoid cartilage, but it is otherwise preserved; after operation it is present as a lax sphincter and can be put to useful purpose as a reed, vibrating under the impact of a column of air escaping from the oesophagus, as we pointed out in 1928 and later (Negus, 1938)



FIG 52—Subject prepared for recording of intrathoracic pressure A double stethograph is employed to record respiratory movements and also the rate of change of thoracic capacity The capacitance meter is on the subject's right next to a glass syringe used to fill the polythene tube with water.
(Medical Unit St Thomas's Hospital)

There has been much discussion about the site of the pseudoglottis in post-laryngectomy speech. It appears to us, in the cases we have investigated, to be at the cricopharyngeus; but in other patients it may be elsewhere between the oesophagus and mouth, wherever the patient can produce a narrowing by muscular contraction. The site of the pseudoglottis must be expected to vary, since it is produced in a muscular tube scarred by operation.

Oesophageal respiration occurs when an oesophagoscope has been passed through the sphincter, to the discomfort of a conscious patient, after laryngectomy, however, there is sufficient control to prevent diversion of air into the gullet, except when desired.

There are three methods of providing a reservoir of air for use after laryngectomy. The first causes air to accumulate in the oesophagus by virtue of pharyngeal swallowing movements; the second further propels this air into the stomach, where a bubble can be observed radiologically, as in Burger's case; and the third draws air into the oesophagus, but not into the stomach, by inspiratory efforts with a relaxed sphincter. The third is the preferable method and the one that can be demonstrated in the best speakers after laryngectomy

A number of investigations have been carried out to demonstrate the method of voice production in laryngectomized patients. Radiography with the oesophagus outlined with barium paste will show the state of the oesophagus during respiration and the various phases of speech. Cineradiography has been used for this purpose

by Dr. John Hodson of University College Hospital, London. It is, however, not easy to analyse the films in detail, as accurate synchronization of sound is difficult. But cineradiography shows conclusively that the oesophagus fills with air before speech and that it progressively empties during speech and that speech is impossible with an oesophagus empty of air. This is confirmed by direct examination with a fluoroscopic screen (Fig. 51). Some observers do not agree with this view and consider that air swallowing and belching are essential parts of the speech mechanism (McCall, 1943; Hayes, 1950); others, however, hold views similar to ours (Froeschels, 1951).

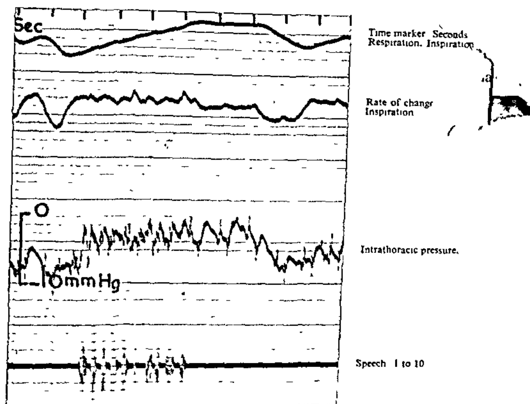


FIG 53 —Speech recording in a normal subject The subject counts one to ten
(*St Thomas's Hospital*)

Investigations recently carried out in the Medical Unit of St. Thomas's Hospital, London, support the views put forward here; accurate determination of intra-oesophageal pressures, in relation to speech, are possible by the following method (Bateman *et al*, 1952, Bateman, 1953).

The patient lies on a couch and a fine bore plastic tube is passed through the nose to the mid-oesophagus (Fig. 52). The tube is filled with water and the meniscus at the end of the tube transmits the intra-oesophageal pressure changes to the Hausen capacitance manometer. No balloon or tambour is required It has been shown that in the normal subject intra-oesophageal pressure is equal to intrapleural pressure (Dornhorst and Leathart, 1952).

Two lengths of air-filled wide-bore tubing are clipped round the thorax and abdomen to act as a stethograph; these tubes are connected to a second manometer (Fig. 52). Alterations in the thoracic capacity can be recorded on photographic paper through the medium of the capacitance manometer (Fig. 53).

[illegible] ... and a sound recording is made

[illegible]

cycle and with the intrathoracic pressure can be made.

Fig. 53 shows speech in the normal subject. It demonstrates, as expected, that speech occurs during expiration, that there is only little air loss from the chest during speech and that the acceleration of air loss is only slight.

It will be seen in this figure that the intrathoracic pressure, as measured in the oesophagus, never rises to atmospheric pressure during quiet speech. But there is an additional factor, namely the elasticity of the lungs which raises the pressure of air in the trachea above atmospheric pressure and thus produces the expiratory air stream which is forced through the glottis.

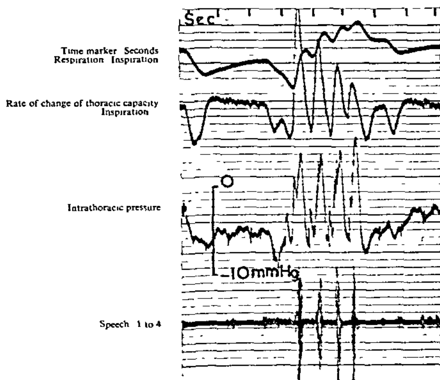


Fig. 54.—Tracing of respiratory excursions, thoracic pressure and speech waves in a subject of laryngectomy
(*St Thomas's Hospital*)

By contrast, Fig. 54 shows speech in a subject after laryngectomy. It will be seen that speech occurs only during expiration, and only when the intrathoracic pressure is raised above the atmospheric pressure. It will be seen also that the air loss during speech is very great and that thus the patient is limited to only a few words at each expiration. It is interesting to note that a patient with a large patent tracheostome can raise the intrathoracic pressure to several millimetres of mercury above atmospheric pressure.

Fig. 55 shows the same subject speaking with the photographic paper running at a faster rate; the vertical lines record one-tenth of a second. It will be seen here that during inspiration and before speech begins the intrathoracic pressure as recorded in the oesophagus suddenly jumps to atmospheric pressure and then falls again. This is interpreted as being the time when the cricopharyngeal sphincter opens and allows the oesophagus to fill with air. The sphincter then closes and the pressure drops again till expiration and speech begin, when the intrathoracic pressure is raised above the level of the atmosphere.

Recordings of oesophageal speech have also been taken on a kymograph running at a fast rate and thus spacing out the phases of respiration.

Fig. 56 is from a patient who spoke well. It will be seen that the beginning of each

word, indicated by the [illegible]
comm [illegible]
of the [illegible] sphincter.

These recordings and radiographs accord *with the* theory of post-laryngectomy speech enunciated at the beginning of this section; we believe that this interpretation of the mechanism is essentially correct and that the air is not swallowed and then belched. We also believe that the *stomach* plays no part as a reservoir of air available for speech, and that once air has reached *the stomach it is* lost for the purposes of post-laryngectomy speech. This *view is opposed* to that expressed by Burger and Kaiser (1925), who demonstrated that the patient swallowed air into his stomach and regurgitated it for *speech. It may be that isolated patients do develop this faculty,* but none of the several patients investigated at St. Thomas's Hospital had the faculty of using air once it had reached the stomach.

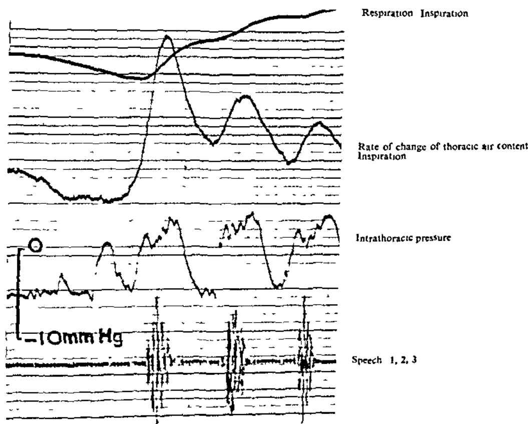


FIG 55.—Recording from the same subject as in Fig 54 with the photographic *paper running at* a faster rate
(St Thomas's Hospital)

Education in oesophageal speech

Training patients varies very considerably in its difficulties. Some subjects of laryngectomy acquire the faculty of speaking spontaneously and with little effort; others are very slow in learning. The desire to learn is of paramount importance; the intelligent patient of moderate age is more facile than the older and duller individual. Perseverance is necessary; in some cases it is only after the lapse of a year or more that the ability to speak is acquired.

It is undesirable for the patient to commence by *whispering on the lips*; he should be instructed to communicate in writing until he begins to produce clearly audible and intelligible words.

Example is of great benefit and a good oesophageal speaker will often be of more value as an instructor than anyone who, by virtue of an intact larynx, is unable to

demonstrate the correct method. The collection of patients without a larynx in classes, under the supervision of a speech therapist, is of considerable value; in some centres clubs are formed as a means of encouragement (Hospital Progress, 1950).

The crico-pharyngeal sphincter, having been detached from the cricoid cartilage, is more lax than is normal and allows air to enter the oesophagus with ease. It may be that the patient will swallow or inspire air involuntarily and will emit it with a belching sound; if so he has made the first step in his re-education.

Although the drawing of air into the oesophagus by an inspiratory effort is the eventual method to be adopted, yet as a commencement it is permissible to teach the patient to gulp air by a swallowing movement.

Alternatively he may be given a little Seidlitz powder, not mixed, but taken in two parts, to combine in the oesophagus or stomach and to give off CO_2 for expulsion and utilization in phonation.

The blowing of air into the oesophagus through a rubber tube connected with a bellows has been suggested, for some, the sucking of a boiled sweet is useful.

Eventually the patient should learn to draw air into the oesophagus without swallowing and should retain it, to be emitted at will; voluntary relaxation of the crico-pharyngeus is necessary Articulation follows easily, once the power of producing sound in the pharynx has been acquired

The length of sentences varies according to the ability of the individual, dependent on his conservation of air. Generally, small and frequent inspirations are used to produce three or four words, so that a sentence is somewhat interrupted in its sequence. Improvement follows with practice.

The taking of air should be almost silent; its expulsion is usually accompanied by a slight sound of bubbling, owing to the passage of air from the oesophagus through secretion collecting in the hypopharynx.

It is important for the patient eventually to avoid forced respiratory movements while he is speaking from the oesophagus. He must learn to conserve the supply of air and not to mask the words he produces by waste of air escaping from the lungs through the tracheostome Fig 56 shows the slight extent of respiratory movements.

In one patient referred to us, air was drawn satisfactorily into the oesophagus, but its escape, in an attempt to produce speech, resulted in forward ballooning of the oesophageal wall, accompanied by forced expiratory efforts The insertion of an accurately fitting plastic tube of a size to fill the trachea and to hold back the anterior oesophageal wall enabled a useful and distinct voice to be attained.

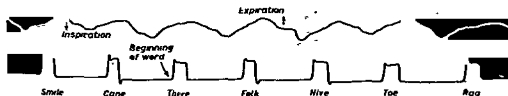


FIG 56—Timing of oesophageal speech in relation to respiratory movements in a patient after laryngectomy A stethograph records the phases of respiration and a writer actuated by a tambour indicates the point at which articulation occurs.
(Ferens Institute, Middlesex Hospital)

ALTERNATIVE METHODS

Artificial larynx

To replace the natural reed of the normal glottis or the substitute reed provided by the crico-pharyngeal sphincter, various pieces of apparatus have been designed by Tapia, Mackenty and others. That most commonly used is one actuated by the patient's expiratory effort.

FIG 58 —Recording of the same subject as in Fig. 57, but on a faster drum Oscillograph recordings of each word are added above the middle curve, which shows the air pressure required to actuate the metal reed Expiratory movements are slight and well controlled, the production of each word synchronizes with the beginning of an expiratory effort

FIG. 59 – A less adept subject using an artificial larynx with greater expiratory effort, the pressure to actuate the reed rises to a maximum of 150 mm H_2O The tracing is taken from right to left

(Figs 58 and 59 Ferens Institute, Middlesex Hospital)

Whisper

By forcing a little air through the teeth and lips by movements of the cheeks and tongue, some patients are able to make themselves understood, but only in a soft whisper.

The method is sometimes adopted by subjects of laryngectomy, but it is to be discouraged, since it precludes determined efforts to learn a better means of vocal communication

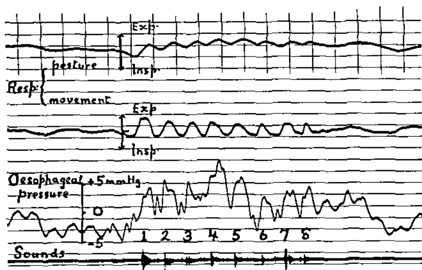


Fig 60 [illegible] the [illegible] with [illegible] the [illegible] vere spoken [illegible] during phonation

(*Ferens Institute Middlesex Hospital*)

PHARYNGO-OESOPHAGO-LARYNGECTOMY

When the lower end of the pharynx and the upper end of the oesophagus have to be excised, in cases of post-cricoid carcinoma or for growths in the pyriform fossa, it is usually necessary to remove the larynx as well The trachea then opens externally above the sternum, as in total laryngectomy. The gullet is restored by a plastic operation, by means of a skin graft or skin flaps, the crico-pharyngeal sphincter is, of necessity, sacrificed

It is consequently very difficult to acquire an oesophageal voice and it is probable than an artificial larynx will be required. Rarely, a patient learns to speak from the oesophagus, the vibration of the column of air is somewhere in the newly reconstructed pharynx, and possibly at the junction of oesophagus and skin-tube (Fig 60). Even if no voiced speech is acquired the patient will generally be understood by those habituated to his or her manner of speech by means of a whisper on the lips.

ACKNOWLEDGEMENTS

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(*See also British Surgical Practice* Larynx—Surgical Diseases of, Vol 5, page 338, S Key 216)

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HAND RECONSTRUCTION IN LEPROSY

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Leprosy is probably the commonest cause of paralysis of the hand in the world today. It is usually a low median and ulnar palsy, producing a classical claw hand (or *main en griffe*), with thenar paralysis.

It has recently been demonstrated in more than one centre that standard methods of orthopaedic surgery are applicable with very slight modification to leprosy patients, and that muscle balance can be restored to their claw hands.

The first part of this article is an account of the paralysis and deformity of hands in leprosy, and will be of interest to surgeons who are likely to see leprosy patients. The second part is an analysis of median and ulnar palsy, with a discussion of the scope of reconstructive procedures in this condition, and must appeal to the general surgeon. It contains a description of the operations that are now in use at the hand-surgery unit at the Christian Medical College, Vellore, where about five hundred muscle-balance operations have been performed on leprosy patients. This section is applicable to cases of claw hand from any cause, and not only to leprosy patients.

DISTRIBUTION OF NERVE LESIONS

Not all patients with leprosy have motor paralysis. In neural leprosy paralysis is common as an early symptom, and often produces severe disability. In lepromatous leprosy paralysis may sometimes be absent, and when it does occur, it is usually a later symptom, and may be incomplete. From the surgeon's point of view the most interesting aspect of the nerve involvement is its localization and limitation. In both neural and lepromatous leprosy the localization is the same, and is astonishingly uniform and circumscribed.

The earliest motor paralysis is commonly that of the ulnar nerve above the elbow. There is swelling of the nerve in the lower three to five inches of the arm, ending rather abruptly below the olecranon groove. Some or all of the muscles supplied by the ulnar nerve may be paralysed. The ulnar-supplied intrinsic muscles of the hand are the most constantly affected. Power in the flexor carpi ulnaris and ulnar-supplied half of the flexor profundus is often lost also, but these muscles sometimes escape.

Lesions of the median nerve come second in order of frequency, with paralysis below the wrist. There is a swelling in the lower three inches of the median nerve in the forearm ending or diminishing in the carpal tunnel, and all the muscles supplied by this nerve in the hand may be paralysed. The median nerve muscles in the forearm are regularly spared, as their nerves of supply leave the median nerve well above the affected segment.

The radial and posterior interosseus nerves are rarely paralysed, but when they are it seems to be at a point about two inches above the elbow, and every muscle supplied below this point may be paralysed. If any one of the extensor muscles is affected, then all are likely to be paralysed.

The motor nerves to the upper arm, shoulder girdle, trunk and thigh are apparently

immune to paralysis, but there are three other sites of paralysis which will be mentioned for interest, though they do not affect the hand. They are in the lateral popliteal nerve at the fibular neck, the posterior tibial nerve above the lateral malleolus, and the facial nerve.

Anatomical grouping

Patients may thus be divided into three groups according to the extent of paralysis. *First a large group* who have only ulnar palsy, with clawed fingers but a useful thumb. In this group are some who have minimal clawing of the index and middle fingers, because of strong median-supplied lumbricals, and some who have a thumb that is very unstable in pinching because of an unstable metacarpophalangeal joint, due to loss of the adductor and short flexor of the thumb.

The second group, even larger than the first, consists of those with high ulnar and low median paralysis. These have complete clawing of all fingers, and complete small-muscle loss in the thumb, giving inability to oppose the thumb. These patients have only three useful movements left in their hands. The first is a sideways pinch between the thumb and the edge of the index metacarpal. The second is an interdigital squeeze between the adjacent sides of two fingers, powered by the adduction that accompanies flexion of fingers The last is the use of the clawed fingers as a hook, for lifting and holding articles that are pressed into the curve of the fingers. The strong long flexors easily maintain this curve against considerable force.

The third group is a very small one and consists of patients with a high ulnar, low median and high radial palsy. These have quite useless hands, because although they have good median-supplied flexors, they are not able to use them effectively with a dropped wrist.

ANALYSIS OF HAND DISABILITY

Fingers

The anatomy of the hand has received a good deal of attention in recent years; in particular, the function of each part of the intrinsic muscle complex and finger extensor mechanism has been analysed and discussed. We now have several clear and detailed accounts of the anatomy and physiology of finger motion to guide us in reconstructive surgery. We will not attempt in this account to do more than summarize anatomical and physiological points that are relative to this discussion.

It has been our policy in the hand-surgery unit in Vellore to follow up as many as possible of our hand reconstruction cases in our rehabilitation centre. Here, each [illegible]

overcome the residual disability of the hands.

This experience has taught us a great deal about the relative value of different reconstructive procedures in their use to the working man in his trade. It has also demonstrated that certain aspects of the activity of the hand in actual use need to be emphasized in the surgical literature. The complexity of muscle interaction and co-ordination has, in the hands of most writers, masked the essential simplicity of the resulting movements of the hand in action. It is our purpose now to analyse as simply as possible the really essential movements of the hand and to show how they can be reproduced in hands which have intrinsic paralysis.

Functions in the normal hand

The hand fulfils the great majority of its functions by the use of the following elementary actions.

(1) A grasp between the fingers and the palm of the hand (for small objects, and handles of some tools).

(2) A grasp between the fingers and the thumb (for large objects, and handles of tools).

(3) A pinch between the pulps of the thumb and index and long fingers (for very small objects, and for tools and instruments requiring precision of grasp and movements).

There are in addition many minor movements which become important in special occupations, such as tapping with the fingers in typing or piano playing. The more complex finger movements such as are involved in tying knots or doing up buttons are beyond our powers of analysis, but will be mentioned in connexion with rehabilitation.

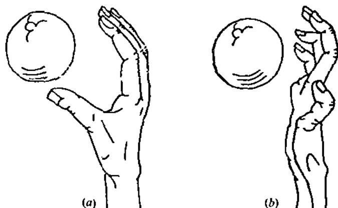


FIG 61—(a) Normal hand. First stage of grasp, (b) claw hand First stage of grasp The fingers in the claw hand can be opened widely enough to grasp the object

Grasp.—When a normal hand grasps an object of moderate size such as a tumbler or an apple between the fingers and the thumb, the action of the fingers can be divided into three stages.

(1) The fingers are opened out until all joints are nearly extended, and the curve of the open hand is wider than the object to be grasped (Fig. 61*a*)

(2) The fingers reach forward to surround the object, bending first at the metacarpophalangeal joints (Fig 62*a*).

(3) The fingers tighten around the object and hold it firmly (Fig. 63*a*).

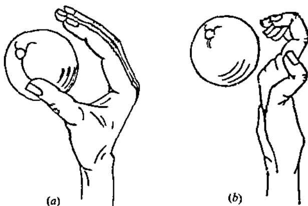


FIG 62—(a) Normal hand Second stage of grasp Metacarpophalangeal joints flexing Interphalangeal joints still extended, (b) claw hand Second stage of grasp Metacarpophalangeal joints are still extended while interphalangeal joints are flexing

Now we will consider how these three actions are performed and why they fail in the claw hand

Because we are concerned only with grasp, and not with more complex movements, we will not discuss the individual actions of the lumbrical and interosseus muscles, but will refer to their combined action as that of the "intrinsic muscles" of each finger.

Effects of paralysis

Stage I.—In stage I of the normal grasp the dominant muscle in each finger is the

extensor, which produces extension of the metacarpophalangeal joint. The secondary muscles are the intrinsics, and these are *responsible for* extending the interphalangeal joints to complete the wide opening of the hand. In the claw-hand grasp *the dominant* muscle of stage I is still active, but *acting alone it is* able only to extend the metacarpophalangeal joints, leaving the interphalangeal joints flexed, thus producing the "claw" that has named the condition *(Fig. 61b).*

It has been shown that if the *metacarpophalangeal* joints are artificially stabilized short of hyperextension, the extensor muscles are *then* able *to* extend all of the finger joints. This observation has led *to a number* of operations for the correction of claw hand depending upon either tenodesis, capsular shortening, or bone block, to stabilize the *metacarpophalangeal joint in slight flexion*, and thus allow full extension of all other finger joints. Any of these procedures will achieve the fully extended hand of stage I, *but must prove a handicap in or may even prevent the second stage of grasping.*

Stage II.—In the stage II of grasp *in the normal* hand *the* important muscles are the intrinsics, which can flex the metacarpophalangeal joints and extend the interphalangeal joints by themselves, although in actual fact the long extensors usually play the secondary rôle *in this phase by extending* the interphalangeal joints while the intrinsics flex the metacarpophalangeal *joints. As the hand continues to flex, the* long flexor muscles take over from the long extensors and the interphalangeal joints flex around the object to be grasped.

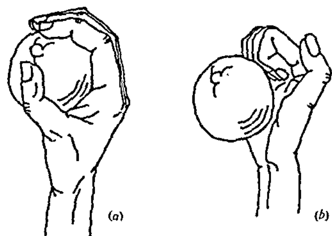


Fig. 63.—(*a*) Complete grasp. Normal hand; (*b*) completed grasp. Claw hand. Metacarpophalangeal joints have now *flexed, but the* preliminary flexion of the interphalangeal joints has rendered the grasp useless.

Now in the claw hand the dominant muscles of stage *II* are paralysed. Their function is to initiate flexion by bending the metacarpophalangeal joint while the interphalangeal joints are still extended. The intrinsics are the only muscles that can flex the metacarpophalangeal joints without first flexing the interphalangeal joints.

It can be seen from Fig. 62*b* that if the long flexors initiate flexion in the absence of the intrinsics, it makes the ends of *the fingers curl up* into the palm instead of reaching out to surround their object. This aspect of intrinsic paralysis has not previously been emphasized in surgical literature, but we believe it to be the most disabling factor of all, and more serious than the well-known *disability of stage* I. None of the operations that attempt the correction of claw hand by static limitation of extension of the *metacarpophalangeal joint* have any effect on the second stage, because this must be performed by a muscle which can act *primarily* on the metacarpophalangeal joint and move it into flexion in advance of the interphalangeal joints.

The Bunnell and the Fowler procedures provide *such a* muscle, and will be discussed in the next sec

Stage III.—

all the power

paralysis (Fig. 63*b*) because the shape of the grasp

object grasped, and no muscle balance is needed. The powerful long flexors maintain the grip, and the muscles of shoulder, elbow and wrist wield the hand that has now grasped the tool.

When an object is grasped between fingers and the palm, the finger action is the same as has been described, except that stage I, the wide-open hand, is not necessary for small objects. For a pinch action between fingers and thumb, the fingers begin with the stage II already described, and then stabilize against the thumb with most of the power provided by the intrinsics and the flexor profundus.

To complete the summary of the muscle balance of grasp and pinch, the movements of the thumb must be analysed, but this will be discussed after the physical and operative treatment of the fingers have been described.

Pre-operative care

Physiotherapy and splintage.—Because stage I of the grasp is not of much value if stage II fails, patients rarely bother to extend their fingers as fully as possible. They therefore develop a contracture of their interphalangeal joints surprisingly early. The dry non-sweating skin is often hyperkeratotic and may develop cracks if forcibly stretched.

A programme of active exercises should be instituted, and the patient taught how he can actively extend his interphalangeal joints if he presses his proximal phalanges forward into flexion using his other hand.

As a preliminary to his daily exercises the patient is instructed to rub a vegetable ... wax baths are a useful form of ... he contractures gradually is to ... o prevent pressure sores which the patient will not notice because of his skin anaesthesia

At the time a neural leprosy patient presents himself for surgery he usually has sores and burns on his fingers, and quite probably will be unaware of their presence. A long period of pre-operative preparation must be demanded, to allow time for ... nbered. ... tient to ... disuse of his fingers that is encouraged by his anaesthesia. The loss of fingers that is traditionally associated with leprosy is in fact almost entirely avoidable if patients will take care of their hands, and learn to anticipate and avoid hazards in daily activity from which pain protects healthy people.

The patient should be having routine anti-leprosy treatment, which may be continued throughout the operation period. We have operated upon cases in all stages and types of the disease, and do not feel that there is any contra-indication to operation in the course of leprosy, except for reasons that would contra-indicate elective operation under any circumstances, of anaemia, fever, and skin eruptions.

Anaesthesia

Most neural leprosy patients do not feel skin pain in their hands, and the only discomfort of operation is caused by tendon manipulation and by the tourniquet. A full pre-medication plus light analgesia is all that is needed; a brachial plexus block is satisfactory.

General management.—A bloodless field is, of course, essential, and a pneumatic tourniquet should be used. It is probably wise to keep the pressure below 225 millimetres and to release it at the end of an hour and a quarter to an hour and a half, as the nerves in leprosy are harmed by prolonged ischaemia. The tourniquet may be re-applied for a second period if necessary. The importance of fine instruments and an atraumatic technique has often been stressed by hand surgeons, and is not less

important in leprosy. It is also important that all parts of the operation should be carefully planned and that a fairly speedy technique be developed because the average hand requires five tendon transfers, and sometimes an arthrodesis as well. The only alternatives are a rather prolonged operation or else repeated operations on the same hand, with increased scarring and long hospitalization. For any but an experienced hand surgeon it would be wise to operate on two fingers at a time, and on the thumb at a separate session. With increasing experience all five digits can conveniently be operated at one session.

Procedure recommended.—The operation which we have used most extensively and recommend for clawed fingers is a modification of the Bunnell flexor sublimis transplantation. It is suitable for cases in which the joints are still mobile, or have been made so by exercise and elastic splinting. The pre-operative passive range of movement should be from full flexion to at least 120°. If the metacarpophalangeal joints are supported in the flexed position by the surgeon, the patient should be able to extend his proximal interphalangeal joints actively to at least 90°, otherwise a sublimis transfer will not be likely to restore a full range of movement, even if the joints are mobile.

Operative technique

On the radial side of each finger a mid-lateral incision is made along the whole proximal segment, including the first joint. The edge of the dorsal expansion and lumbrical tendon is exposed and cleaned. The flexor sheath is then opened near the interphalangeal joint, and the flexor sublimis tendon divided as near to its insertion as possible, the finger being flexed. The two halves of the tendon are separated from each other back to the point where they divide to encircle the profundus tendon.

The palm is next opened by a transverse incision at the level of the main transverse crease, and the divided tendons pulled out into the wound. Each tendon is threaded down the lumbrical canal to its own finger, and passed through a slit in the lumbrical tendon at the base of the finger and then sutured to the edge and dorsum of the extensor-expansion just proximal to the interphalangeal joint.

The sublimis tendon to the ring finger is required for the thumb, so it is not used, but the halves of the sublimis to the middle finger are split back for about three inches, and one half threaded down the lumbrical canal to the middle finger, and one half used for the ring finger.

The tendons are sutured under fair tension, greater for stiff fingers, less for mobile fingers. Average tension is about half-way between complete relaxation and full stretch when the wrist, and all finger joints are held at 180°. The little finger seems to need greater tension than the others.

The hand is immobilized post-operatively with the wrist straight, the metacarpophalangeal joints flexed to 90°, and the interphalangeal joints within a few degrees of full extension. The immobilization is maintained for about three weeks, and then active exercises are started.

Alternative procedure

In Fowler's operation the extensor indicis and extensor minimi digiti tendons are used. Each is split into two and threaded through the interosseus spaces, to be attached to the lumbrical tendon or dorsal expansion of each finger. We have not had a very extensive experience with this operation, but use it for fingers in which the flexor profundus is weak, in the ring and little fingers. In most cases this weakness is not significant, because all the tendons of the profundus usually move as one. Even when the ulnar half is paralysed, it moves to some extent with the rest. This should be tested pre-operatively, because if the profundus is not active in a finger, it is obviously bad to remove the sublimis.

Unusual features

Interphalangeal joints are sometimes found to be hyper-mobile, and to be passively hyper-extensible even in cases of claw hand. In such cases the Bunnell transfer is liable to produce a new deformity, the "intrinsic-plus" hand, with hyper-extended proximal interphalangeal joints and flexed terminal joints, because of the loss of the sublimis from its usual location. In this type of case one may prevent the new deformity by providing an anterior ligament or "check-rein" for the proximal interphalangeal joint. This can be done by dividing one half of the flexor sublimis tendon further proximally than usual and using the long stump left behind as a ligament. If the finger is held exactly straight, and the division is made just proximal to the point at which the sublimis disappears under cover of the fibrous part of the flexor sheath, then the distal stump of the tendon may be sutured to the edge of the digital vaginal ligament. This will effectively prevent hyper-extension of the joint, and the flexion of the terminal joint that follows it.

In cases in which the proximal interphalangeal joint is too stiff to allow extension, even after exercises and splinting, the most satisfactory operation is arthrodesis of the interphalangeal joint Movement at the metacarpophalangeal joint is rarely limited and it develops an extra range of active movement if the interphalangeal joints are fused, especially if the fusion is at an angle just above a right angle. We usually arthrodese the middle, ring and little fingers at about 90–100° to suit a grasp against the palm, for holding handles of tools, and the index finger at a wider angle to suit a pinch against the thumb. This angle should be decided after the thumb has been reconstructed and is often about 135°. If appearance is more important to the patient than function, then wider angles must be chosen for all fingers. In such cases a full thickness skin graft may be needed on the front of the finger to allow it to open out far enough.

The paralysed thumb

Disability

If the median nerve is paralysed in leprosy, the ulnar nerve is usually paralysed also. This means that one has to deal with a thumb with all its intrinsic muscles paralysed, but with its flexor longus, abductor longus, and extensor longus and brevis intact.

Such a thumb is totally unable to abduct, oppose or pinch. The abductor longus is not really an abductor muscle but an extensor of the metacarpal, because abduction in the thumb should be considered in a plane at right angles to the palm, not parallel to it.

A thumb with its intrinsic muscles paralysed has just one movement left to it which is very useful This is a sideways pinch between the proximal phalanx of the thumb and the side of the index metacarpal. This is a sort of adduction movement, but is powered by the simultaneous contraction of the extensor longus and the flexor longus, both of which have an adductor component. In order to use this movement the more powerful flexor first has to flex the terminal joint of the thumb against the weaker extensor, and then both can exercise their adductor function, having stabilized their flexor-extensor components.

The result of all this is that the patient never uses his thumb except at the lateral edge of his palm and with his terminal joint flexed Thus one commonly sees these cases with a flexion contracture of the terminal joint and with a contracted thumb web. If these two rigid deformities are not corrected before tendon transplantation, then the thumb will never fulfil its normal function

Pre-operative care

Physiotherapy should aim at encouraging active extension of the terminal joint in early cases, by stabilizing the proximal joint in flexion. The extensor longus is not

able to extend the terminal joint if the proximal joint is not stabilized. This stabilization is normally done by the small muscles. If there is contracture, elastic splinting may be tried, but often the contracture is too rigid for that. Attempts to stretch the web by exercises and splintage may also be tried. In our experience these have not been successful. A Z-plasty on the thumb web will widen it, but frequently it is insufficient, especially as the dorsal surface of the skin of the web needs a lot of extra length to allow for the rotation of the thumb into the opposed position. We are now using the following operation as a preliminary to the tendon transfer on the thumb when the web is narrow, or the dorsal skin limits rotation (Fig. 64).

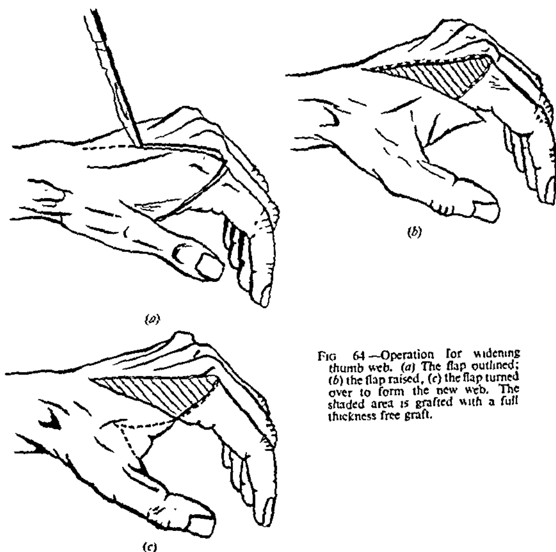


Fig. 64.—Operation for widening thumb web. (a) The flap outlined; (b) the flap raised, (c) the flap turned over to form the new web. The shaded area is grafted with a full thickness free graft.

... the thumb web
l and continuing
baggy skin over
n turns sharply
the back of the index metacarpophalangeal joint...
back at 70° and sweeps across the back of the hand to finish just distal to the wrist. The third limb of the "Z" runs from the thumb end of the first incision and down the palm of the hand at 70° to the first incision, in the groove between the thenar eminence and the rest of the palm. The outlined triangular flaps are raised, carefully preserving their blood supply, and, in the case of the dorsal flap, taking care to leave a film of gliding tissue over the extensor tendons. The space between the first and

second metacarpals is opened up and the first metacarpal pulled into and held in a fully abducted and opposed position. The origins of the adductor pollicis and first dorsal interosseus muscles will often have to be divided to allow this, and also some adhesions down near the first carpometacarpal joint.

When the correct position of the bones has been achieved, a fine Kirschner wire may be drilled through the neck of the first, and into the neck of the second metacarpal, to hold these bones apart, and in the correct rotational relationship. A separate stab incision may be used for this drill hole, and it should be closed over the cut end of the wire. The wire is removed at the end of six weeks.

The dorsal flap of skin is then pulled across and folded over to form the new web, and its point lies down in the volar gap between the thumb and palm The volar flap is transposed just as in a normal Z-plasty, but cannot of course fill the very large dorsal defect. This skin defect is filled by using a free full-thickness graft of skin from the trunk.

The advantage of this method is that it places the free graft on the dorsum of the hand where it will take, rather than using it in the web where there is no tissue on which it will grow unless one makes a very deep ugly cleft at the web. The only other [illegible]

point to the other, forcing the joint into hyper-extension and inserting a full-thickness free graft into the skin defect. The thumb should then be immobilized with the terminal joint in maximum extension.

Tendon transplantation

Anatomical considerations.—When the full range of passive movement of the thumb has been restored, then a tendon transplantation should be performed to restore abduction and opposition. It is important to remember in this connexion that the important function of the thumb is to oppose the fingers in the movements of grasp and pinch.

For both of these movements the first position of the thumb is that of standing erect, with all joints extended, at right angles to the palm of the hand in all planes for a wide grasp, or leaning a little distally for grasping a small object. The final position of the thumb in the case of a wide grasp remains much the same as the first position, the fingers having moved towards it. For a small object the thumb bends towards the fingers slightly at all joints, and for pinch it commonly bends a little at the metacarpophalangeal joint only.

There are two positions of the thumb which surgeons have laid stress upon but which we believe to be relatively unimportant. One is the position of so-called "full opposition", in which the pulp of the thumb is brought across the palm till it meets the base of the ring or little finger. This may be a good test of the activity of the opponens muscle, but it is hard to think of any functional use for the movement. The other is the "O" position, in which the thumb and index finger meet at their tips to make an "O". This position is used for picking up pins and other very tiny objects, but for all ordinary finger-and-thumb pinching the straight thumb is used, especially if strength is required. In this position the pulps, not the tips of the finger, and thumb meet.

The majority of operations advised for intrinsic palsy of the thumb do not provide for extension of the terminal joint of the thumb, and have to be satisfied with the "O" pinch. Most operations emphasize the opponens position at the expense of the fully abducted erect position.

Campbell Thompson (1942) makes his tendon transfer pull right across the palm, and produces a beautiful opposition of the thumb to the base of the little finger,

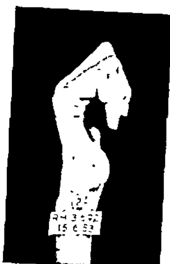
but in our experience the patient cannot get the thumb far enough away from the fingers to grasp a large object. Even Bunnell (1948), who aims his tendon from the



(*a*)



(*b*)



(*c*)



(*d*)



(*e*)



(*f*)



(*g*)

FIG 65 —A case of complete high ulnar and low median palsy due to Hansen's disease, a typical case of claw hand (*a*) Attempting to open the hand before operation, (*b*) attempting [illegible] the same throughout the series

base of the proximal phalanx towards the pisiform bone, favours the opponens action more than the abductor. Our results with his criteria for operation have given too many cases of flexion at the metacarpophalangeal joint on attempted pinch. Riordan (1953) and Littler (1949) have both emphasized the importance of making the new tendon pull in the direction of the abductor brevis, and in addition Riordan has pointed out how the same tendon that abducts the thumb may also be used to extend the terminal joint if it is inserted into the extensor longus tendon.

There seems little doubt that the flexor sublimis to the ring finger is the best muscle to use for the restoration of abduction into the thumb. The wrist flexors and the palmaris longus have too short a range of movement to do all that is needed. Furthermore, use of the sublimis avoids the need for a tendon suture at the wrist.

The operation now described owes much to many authors and is the same in principle as that recently reported by Riordan, with an important variation at the metacarpophalangeal joint.

Technique.—The flexor sublimis to the ring finger is divided near its insertion, through a midlateral incision, and split back to the point at which it divides to encircle the profundus tendon. The same tendon is identified in the forearm through a short transverse incision about an inch and a half proximal to the wrist crease.

A transverse incision is made at the wrist beginning exactly at the centre of the wrist crease and extending to the ulnar side for half an inch The tendon is withdrawn through the forearm incision, passed subcutaneously to the wrist incision, and a second tunnel is made from the radial end of the wrist incision to emerge in a third incision at the metacarpophalangeal joint of the thumb

If these tunnels are made narrow with a probe or forceps, and not widely dissected, then no sling is needed to maintain the angle that the tendon makes at the wrist.

The most difficult part of the operation is to decide the exact point at which the tendon should pass the metacarpophalangeal joint, on its way to its insertion in the extensor tendon. If this point is too far dorsal it may give a hyper-extension deformity of that joint. If it is too far volarwards, it gives flexion of that joint. This latter does not look bad, but makes for an unstable pinch.

Riordan advises that the sublimis tendon should be routed through a slit in the tendon of the abductor pollicis brevis at the level of the metacarpophalangeal joint. This is sometimes a good position. Sometimes, however, it produces a definite flexion of this joint in addition to abduction. We suggest that the fibrous capsule of the metacarpophalangeal joint should be exposed from the tendon of abductor brevis to the edge of the dorsal expansion, about half an inch proximal to the point where these two structures send arching fibres to meet one another. The loose capsule is then picked up with fine toothed forceps and pulled in the direction of the pull of the new tendon If the dorsal part of the capsule is pulled, it will be found to produce extension of the joint as well as abduction. Further volarwards, a pull where the abductor brevis tendon lies will produce flexion and abduction. After a few trials a point on the capsule will be found where a pull will produce pure abduction, with neither flexion nor extension, or preferably with a slight tendency to extension. This is the point at which the new tendon should cross the joint, and it will usually be dorsal to the abductor tendon. The capsule is picked up at this point and a fine knife blade passed in and out through the capsule to make a little tunnel through which the tendon is passed on its way to be inserted into the extensor longus tendon just proximal to the terminal joint. We find that results are better if a fairly full tension is kept on this tendon, enough to hold the thumb up from the palm when the patient is relaxed under anaesthesia This transplant should produce abduction at the carpo-metacarpal joint, abduction at the proximal interphalangeal joint, and extension at the terminal joint.

In some cases it will be found that this operation does not restore full extension

to the terminal joint. This is when the joint has been flexed for many years. In such cases it is best to do a flexor tendon tenodesis across the terminal joint in a position of full extension, or, if the joint is damaged, *an arthrodesis in full extension.*

Advanced paralysis

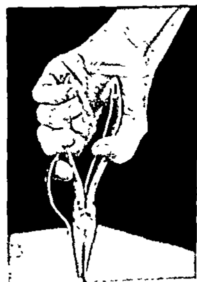
For the occasional patient who has a high ulnar, low median and high radial palsy we advise arthrodesis of the wrist and dislocation of the extensor pollicis longus tendon from the dorsal to the lateral side of the wrist where it can be anastomosed with the tendon of the flexor carpi radialis. The palmaris longus or pronator teres *can be used for the extensors of the fingers. The flexor sublimis to the index, long and* little fingers are used for the paralysed lumbricals as in Bunnell's procedure, and the sublimis from the ring finger used to provide abduction and opposition of the thumb and extension of the terminal joint.

Rehabilitation

When all tendon transfers are completed a leprosy patient is left with a fairly mobile, active hand, *with fair strength in grasp and pinch, and with position sense,* but without cutaneous sensation. Such a hand is clumsy in fine movements, and easily damaged, especially by burns.

Patients on discharge are liable to get quickly discouraged finding that they cannot even now compete with healthy workers, and soon return to their old occupation of begging.

It is of great importance that in the post-operative phase the patients should be



(a)

[illegible] plane has had [illegible] wooden handles attached to suit the grasp of a reconstructed hand, (*c*) the ring handles of this pair of scissors *have been* cut off and simple spring-open lever handles welded in position



(b)



(c)

shown how to make the best use of their hands, and be taught trades in which their skill and dexterity may compete on equal terms with others with normal hands.

We have studied this matter with some care, and our experience is that these patients *do well in a trade or craft in which all the work is done with tools and handles*, and none or very little with direct finger manipulation. Basket-making, at which blind people excel, is an example of a completely unsuitable trade, as so much of the [illegible] e power of most patients, provided some care [illegible] ll tools are adjusted where necessary to fit the strongest part of the grasp (Fig. 66*b*). Handles of a diameter of one to one-and-a-half inches are usually good for chisels and screw-drivers. Pliers and forceps should be fitted with springs to keep the handles open about three inches apart, and be about an [illegible] time is not lost in fumbling to pick up tools from a flat surface. Nails and screws should be kept in racks, and handled with forceps rather than fingers. If small machines, such as jig-saws, can also be supplied to do tedious parts of the work, then these men are well able to produce good work at a speed which will enable them to earn their living.

There are many other trades which may be similarly studied and adjusted to become suitable for hands without sensation.

At the same time that the trade is being taught, the patient must also be helped to understand the need for care of his hands. Every day his hands should be inspected for small cuts or abrasions. If any are found, their cause must be sought, and explained, and their recurrence avoided. A simple first-aid dressing box, preferably using ready-cut adhesive dressings, should be kept in the homes and workshops of all patients, and the danger of continuing to use an infected finger emphasized.

If the rehabilitation team enters with sympathy and enthusiasm into this matter of care of the hands, and regards with real horror and distress the small injuries that the patients tend to ignore, then it will be found that the patients themselves will soon develop a new respect for their hands. They will begin to take a pride in the fingers which they had previously tried to hide, and will take trouble to avoid the trauma which previously had not bothered them because it did not hurt.

(*See also British Surgical Practice* Leprosy, Vol. 5, page 405, S. Key 219)

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PELVIC VISCERECTOMY FOR ADVANCED CANCER

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INTRODUCTION

Pelvic viscerectomy is an attempt at radical surgical treatment of advanced cancer of the uterus, rectum or bladder in certain patients for whom well-established procedures, such as Wertheim's hysterectomy, abdomino-perineal excision of rectum and total cystectomy, no longer permit an adequate clearance of the tumour. Viscerectomy is not an alternative to established procedures, but an extension of the operability range. Direct spread of cancer from one pelvic organ to another and involvement of all three main viscera—uterus, rectum and bladder—are no longer signs of inoperability, as long as the disease is still confined to the pelvic cavity, within the pelvic fascia. Such radical procedures are justified if there is no metastatic visceral or skeletal spread. As a palliative procedure, viscerectomy is indicated in cases of vaginal, rectal and vesical fistulae, when the lack of control of the evacuation of the bowel or bladder is associated with discharge of pus, blood, urine, faeces and tumour, and the concomitant pain and disability.

The operation, first described by Brunschwig (1948) has been rendered possible by the advances in surgical technique, due to the improved methods of anaesthesia, a wide range of antibiotics, a better understanding of the importance of fluid and electrolyte balance and facilities for blood transfusion. These advances have rendered possible the radical attack on pelvic cancer in many cases previously considered inoperable, but the need for sound surgical judgment in the selection of cases is greater than ever. The mortality of the operation is not too great, about 20 per cent. The morbidity can be overcome to a certain degree by the [illegible]

sequelae, such as small intestine fistulae occurring as long as 2 years after the viscerectomy, intestinal obstruction, ascending pyelonephritis, local recurrence of disease or metastatic spread to the skeleton, liver or lungs.

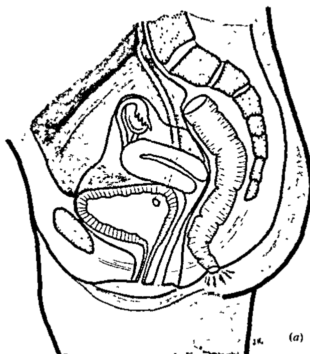
INDICATIONS

Cancer of the uterus

The operation is applicable mostly to cases of cancer of the cervix and only very exceptionally to cancer of the body of the uterus. The patients fall into three main groups.

Untreated advanced disease with vaginal metastasis

Where the malignant growth has invaded the vagina the spread may be on the surface, producing ulceration or satellite tumours; it may, however, be submucosal when the areolar tissue between the urethra and the vagina or the recto-vaginal septum are infiltrated by the neoplasm. In a series of 78,943 patients from 15 different countries,



(a)



(b)

Fig. 67.—(a) Diagram, lateral view, of a female pelvis The red line indicates the tissue removed, namely, bladder, uterus, ovary tube, ureter and vagina, also obturator glands, (b) operation specimen, showing a growth in the cervix involving the vagina adherent to the bladder (Operation by Messrs R Cox and A Briant Evans)

OPERABILITY

Although pelvic viscerectomy has extended surgical help to a number of patients and widened the operative field, there are still strict limitations as regards operability. The presence of distant metastases in the liver, the lungs or the skeleton renders the patient unsuitable for pelvic viscerectomy. Local extension of the disease beyond the pelvic fascia to the muscles of the lateral pelvic floor, to the obturator internus, or adherence to the sacrum, the pubis or the ischium, equally precludes a successful operation, and renders the case technically inoperable. Extensive and adherent lymph nodes in the inguinal regions, or widespread retroperitoneal lymph-node involvement along the aorta or the mesenteric vessels also render the case inoperable. Moderate enlargement of lymph nodes along the internal and external iliac vessels and non-adherent, although enlarged, obturator lymph nodes do not preclude operation. Inoperability may also be due to poor renal function following involvement of both ureters in the growth; but hydro-ureters, bilateral or unilateral and moderate hydronephrosis do not *per se* preclude viscerectomy. Transplantation of grossly dilated ureters in the presence of moderate hydronephrosis often results in recovery of the kidneys and survival for several years.

Oedema of the lower limbs is also a contra-indication to viscerectomy if it is due to lymphatic obstruction, as local recurrence in the pelvis invariably occurs soon after the operation. General disease, such as diabetes, cardiac inefficiency, active pulmonary tuberculosis and gross obesity increase the risk of the operation and must be taken into account, as well as the local extent of the disease, and often are definite contra-indications to operation.

EXTENT OF THE OPERATION

The extent of the operation depends chiefly on the extent of the disease. The tissue removed should include a good margin of healthy tissue beyond the actual tumour. It also depends on the actual site of the disease; thus, involvement of the urethra renders ablation of the urinary bladder inevitable, although only a small portion of that viscus is involved. Similarly, direct invasion of the vagina from rectal cancer renders it essential to remove the uterus. Localization of the disease permits, however, a partial pelvic viscerectomy in some patients and anterior and posterior procedures besides total viscerectomy can be performed.

Anterior procedure

In this method the uterus, bladder, vagina and urethra are excised. This permits an implantation of the ureters into the pelvic colon and colostomy is not needed (Fig. 67).

Posterior procedure

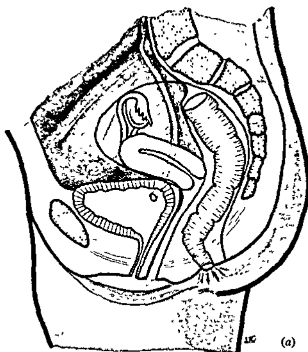
The rectum and the uterus, the anal canal and the vagina are removed when the posterior approach is used. In such a case, the bladder and urethra are preserved, micturition is normal and a colostomy only is necessary (Fig. 68).

Total viscerectomy

In total viscerectomy the rectum, the uterus and the bladder, the anal canal, the vagina and the urethra are removed. A colostomy is required when this method is used and the ureters are implanted into the bowel proximal to the colostomy; or into a separate artificial receptacle, fashioned from a loop of the large or small intestine. This leaves the patient either with a wet colostomy, as described by Brunschwig; or with a colostomy and a separate urinary fistula as practised by the author.

Subdivision of the three methods

The three operations, anterior, posterior and total, can further be subdivided into two groups: those in which the perineum and vulva are free from disease and can be

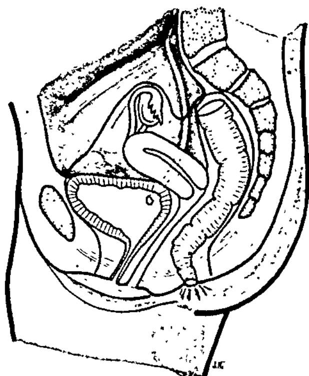


(a)



(b)

FIG 68 —(a) Diagram, lateral view, of a female pelvis. The red line indicates the tissue removed, namely, uterus, ovaries, vagina, sigmoid, rectum and anal canal; (b) photograph of specimen removed by operation (Sir Stanford Cade and Mr Arthur Bell) showing primary growth involving the posterior vaginal wall, the uterus and the rectum.

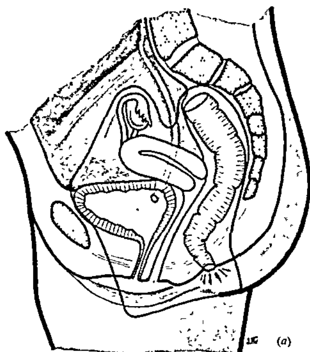


(a)



(b)

FIG. 69.—(a) Diagram, lateral view, of a female pelvis. The red line indicates the tissue removed, namely, bladder, urethra, uterus, vagina, ovary and tube, sigmoid and rectum, also obturator glands; (b) photograph of specimen, showing an extensive carcinoma of the sigmoid, with direct extension into the utero-vesical pouch, forming a large mass which by direct extension has spread into the bladder and practically filled it. The uterus also is involved. This complete operation, however, does not include the external genitalia.



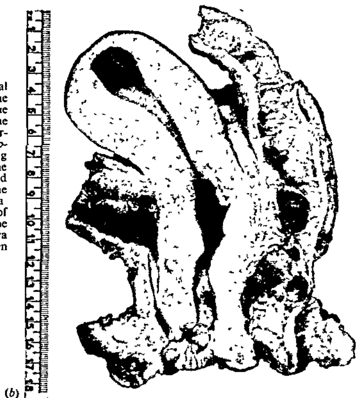


FIG 70 —(*a*) Diagram, lateral view, of a female pelvis. The red line indicates the tissue removed, namely, all the pelvic viscera and the external genitalia; (*b*) photograph of specimen, showing an extensive growth of the uterus, which has destroyed the cervix and involved the entire length of the vagina There is direct invasion of the rectum and of the bladder in front. The vulva and anus have also been removed.

left intact (Fig. 69), and those in which complete excision can only be achieved by the ablation of the perineum, anus and vulva (Fig. 70). The former group is suitable for an operation by the abdominal route, the latter for a combined synchronous abdominal and perineo-vulval excision. Each patient must be studied in great detail and the extent of the operation required must be carefully assessed.

THE MANAGEMENT OF THE URETERS

From the patient's view-point, the management of the ureters is the main difference between this operation and the usual operations for excision of the rectum or for hysterectomy. It is necessary to explain to the patient that transplantation of the ureters may mean the voiding of urine per rectum, the presence of a wet colostomy or the presence of two artificial orifices, the colostomy and the urinary fistula. The state of the patient when a colostomy can be avoided and the ureters are implanted into the pelvic colon is no doubt the least uncomfortable, and nearly always, full control is gained in a short time; the patient becomes aware if he is to evacuate the bowel, or merely to pass urine by the rectum. This operation in the presence of normal rectum and anal sphincters has been practised for many years as the inevitable concomitant of a total cystectomy.

Wet colostomy

It is of great interest to discuss the advantages and disadvantages of a wet colostomy as compared to two separate orifices, a dry colostomy and a urinary fistula. The advantages of a wet colostomy are that the operation is simpler and quicker and there is only one orifice requiring attention. However, these advantages are heavily outweighed by the disadvantages. There is a complete lack of control of the colostomy opening; there is a constant flow of urine diluting the intestinal contents which necessitates wearing a bag containing a mixture of urine and liquid faeces. In addition there are recurrent attacks of ascending urinary infection, with pyelitis, renal pain, fever and general ill health. Such attacks are more frequent in cases of wet colostomy than when the anal sphincter is intact and there is no colostomy. A separate urinary fistula is advantageous in that an ascending urinary infection is avoided; the urine in [illegible] colostomy to act regularly and intermittently.

It is the author's opinion that a separate urinary fistula is the method of choice and a great advantage over a wet colostomy.

TECHNIQUE OF PELVIC VISCERECTOMY

Pre-operative investigations

Patients considered for pelvic viscerectomy require detailed clinical and laboratory investigations. The actual site and local extent of the disease must be carefully assessed, and this, in most cases, warrants an examination under anaesthesia to enable careful [illegible] essential as in many [illegible] e of involvement; even under cystoscopic examination the [illegible] have a doubt as to actual state of the bladder, and cystoscopy combined with rectal palpation is of help. Sigmoidoscopy is carried out at the same time.

X-ray examination of the chest, spine and pelvis should be carried out in all cases, as clinically silent skeletal or pulmonary metastases can otherwise be overlooked. Intravenous pyelography followed, when indicated, by retrograde pyelography is important; the state of the ureters and of the kidneys is thus revealed. Hydro-ureter is found not infrequently, also some degree of hydronephrosis; neither of these is a

definite contra-indication to the operation unless the renal function is poor. Implantation of dilated ureters has been successfully carried out in a number of patients with subsequent regression of the hydronephrosis. A blood count is carried out and an estimation is made of blood urea. Blood transfusion in cases of low haemoglobin should be done before the operation and the general state of the patient should be carefully assessed.

Rectal or colonic washouts are given daily 3 days prior to the operation. Four days preceding the operation Sulphasuxidine should be started and after 2 days have passed *streptomycin should be given, 1 gramme, daily by mouth.*

Anaesthesia

It is the practice at Westminster Hospital to use hypotensive drugs during anaesthesia. The controlled lowering of the blood pressure renders the operation more accurate, blood loss is limited to a minimum and the degree of surgical shock greatly diminished. It has also been found that following such extensive operative procedures, the post-operative state is considerably better and gives rise to less anxiety if hypotensive drugs are used.

Position of patient

If the total operation is performed, including a perineal-vulval resection, the patient is placed in the Trendelenburg-lithotomy position. This position used in the synchronous combined resection of the rectum enables two surgeons, working simultaneously, to carry out the abdominal and the perineo-vulval parts of the operation, without any change of the patient's position. The Trendelenburg position is used when the abdominal part of the operation only is undertaken.

The abdominal phase

The abdomen is opened by a midline incision extending from the pubis to the umbilicus. If removal of the bladder is contemplated, the umbilicus is excised, as later the urinary fistula will be placed in the upper part of the incision. The liver is palpated for metastases and the pre-aortic, iliac and obturator lymph nodes examined. Obvious extension of the disease to glands above the aortic bifurcation renders the case inoperable and the viscerectomy is abandoned. The local extent of the disease is ascertained by inspection and palpation; the growth itself is disturbed as little as possible, and any adherence between the uterus, bladder and rectum is carefully *preserved; there is obviously no advantage in separating such adhesions which prevent* spilling of tumour cells into the operation area. The small intestines are packed off by suitable moist pads. The resection is carried out in stages as follows.

(1) The peritoneum over the bifurcation of the aorta is incised and the incision extended distally and laterally over the right common iliac artery and along the external iliac vessels to the lateral wall of the pelvis. The right ovarian vessels are now exposed, ligated and cut across. The right internal iliac artery and vein are ligated and divided. The retroperitoneal tissues along the external iliac vessels, including the lymph nodes, are dissected downwards and medially. The round *ligament of the uterus is divided close to its lateral end. The obturator lymph nodes* are dissected from the obturator fossa; minor veins are divided, but the obturator nerve is dissected free and preserved and displaced laterally towards the lateral pelvic wall. The external iliac artery and vein are carefully preserved.

(2) Attention is now directed to the left side. The first stage here is similar to the first stage of an abdomino-perineal excision of the rectum. The sigmoid colon is lifted upwards and medially, and the peritoneal attachment divided; this enables the bowel and its mesentery to be dissected medially from the posterior abdominal wall. The left ovarian pedicle is exposed, clamped and cut across. The mesentery of the

sigmoid colon is divided and the bowel cut between two De Martel's clamps. Dissection is then continued similarly to that already done on the right side: the internal iliac vessels are clamped and divided, the obturator fossa cleared, preserving the left obturator nerve and the external iliac artery and vein. The left round ligament is cut across at its lateral end.

Throughout these phases of the operation, both ureters have been displayed but not disturbed. They are now divided with scissors at a point free from disease and well away from the broad ligaments of the uterus. The proximal part of each ureter is left undisturbed at this stage of the operation.

(3) The distal part of the pelvic colon is dissected free and the pelvi-rectal junction and posterior part of the rectum separated from the hollow of the sacrum and mobilized down to the pelvic floor.

(4) The peritoneum of the anterior abdominal wall is cut across at its reflection on to the bladder. The bladder, together with the prevesical fat, is separated by blunt dissection from the pubis. This dissection is continued to the lower edge of the pubic symphysis, till the urethra is reached. In the male, dissection separates the prostate from the retropubic space till the urethra is reached, and both vasa are cut across. The bladder is now free, except at its attachment to the urethra. If the operation is entirely abdominal and no perineal-vulval phase is done, the urethra is cut across at this stage. The proximal half of the vagina is dissected free and divided and the rectum cut across just above the anal canal. Neither the vagina nor the anal canal is sutured. They are left open and the pack of Vaseline gauze to be used to fill the true pelvis is brought out through the vagina.

Completion of the operation

The pelvic contents having been removed, the surgeon responsible for the abdominal phase proceeds with the colostomy and the fashioning of a new artificial bladder into which the ureters are inserted.

If the sigmoid loop is of sufficient length and the descending colon has been adequately mobilized, a small portion of the terminal part of the colon, about 3 inches in length, is used to fashion a receptacle into which the ureters are implanted. As an alternative, a similar procedure can be carried out using a portion of the small intestine and restoring the continuity of the small bowel by end-to-end anastomosis.

The perineal-vulval phase

This phase is preferably carried out by a second surgeon working synchronously with the surgeon responsible for the abdominal phase. A purse string suture closes the anus. The vulva is completely excised if involved by disease, otherwise the labia majora are preserved. The clitoris is also preserved, except in cases of primary carcinoma of the vulva. An elliptical incision is made extending from the coccyx, surrounding the anus and each side of the vulva at the selected site (including or excluding the labia). The incision is deepened till the levatores ani muscles are exposed and these are cut across at their lateral attachment. The ischio-rectal fossae are dissected [illegible] ulated from the sacrum. The incision is deepened anteriorly [illegible] meet each other's territory and [illegible] a by dividing the remaining few fibres attaching the urethra to the pubic arch. The skin of the perineal-vulval wound is closed completely with interrupted sutures allowing a small space for the end of the Vaseline gauze pack introduced into the pelvic cavity.

The making of an artificial bladder

The mesentery of terminal part of pelvic colon is carefully examined; a portion of the bowel about 3 inches long is clamped off with a De Martel's clamp. Its mesentery is divided so as to preserve the blood supply (*see Fig. 71*), and this small loop with

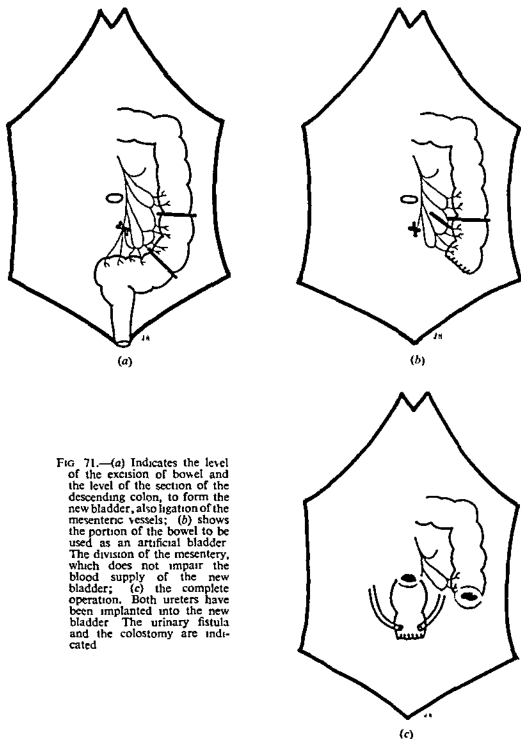
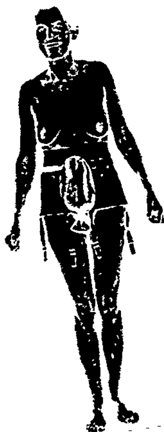
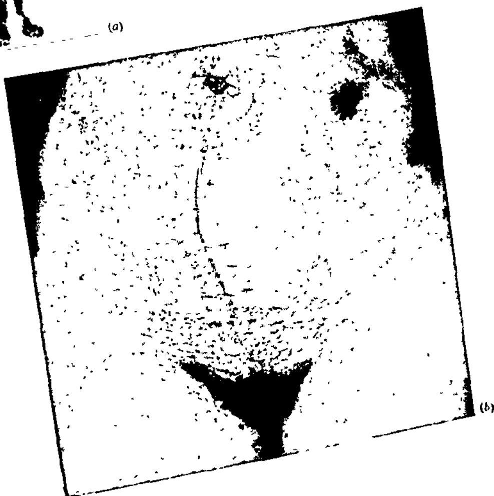


FIG 71.—(*a*) Indicates the level of the excision of bowel and the level of the section of the descending colon, to form the new bladder, also ligation of the mesenteric vessels; (*b*) shows the portion of the bowel to be used as an artificial bladder The division of the mesentery, which does not impair the blood supply of the new bladder; (*c*) the complete operation. Both ureters have been implanted into the new bladder The urinary fistula and the colostomy are indicated

its blood supply remains hinged at its apex to the mesentery. The distal portion is closed with two layers of sutures. The proximal end is left open. Both ureters are then implanted into the loop, one on each side. The simplest method is used. A small incision is made into the bowel. A catgut stitch on a curved non-cutting needle is passed through the edge of the cut ureter and tied, the needle is then passed through



(a)



(b)

FIG. 72.—(a) Photograph of patient following total viscerectomy, without removal of the external genitals. Belt shown; (b) shows abdominal scar and at the site of the umbilicus, which has been excised, is the opening of the new bladder, to which the bag is attached. In the left iliac fossa is the opening of the colostomy.

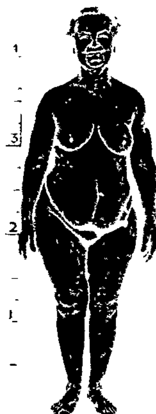


Fig. 73.—(*a*) Patient who has undergone total viscerectomy of all her pelvic organs and the complete excision *of the external genitalia, perineum and anus* Photograph shows the abdominal scar and urinary sinus leading to the new bladder immediately on the left of the laparotomy scar and the left iliac colostomy; (*b*) shows the completely healed perineo-vulval area *after excision of the vulva and the anus*

(*a*)



(*b*)

The loop drains mucus through the fistula, but otherwise gives rise to little inconvenience.

In the series of 15 cases of pelvic viscerectomy, it became necessary to re-open the abdomen in 5 patients: 1 case was for intestinal obstruction due to a solitary band of adhesion, 2 cases were for urinary fistulae, and in 2 other cases for small intestine fistulae—all the 5 patients recovered. In all 5 cases, 10–12 months had elapsed since the pelvic viscerectomy.

The points of interest to be noted are that the raw surface is completely covered by peritoneum, and the opening of the true pelvis is lined by coils of small intestine.

MORTALITY AND END RESULTS

In Brunschwig's original series of 22 patients, the operative mortality was 23 per cent, or 5 deaths (Brunschwig, 1948). In the author's personal series of 15 patients, the operative mortality was 20 per cent, or 3 deaths. There seems to be little doubt that with increased experience, the mortality will be reduced, and it must be remembered that all the patients were in a very advanced stage of the disease, technically inoperable by any other method except viscerectomy. The expectation of life in all patients was limited to a few months, and the discomfort from the recto-vaginal and vesical fistulae nearly beyond endurance. Of the remaining 12 patients, 8 died subsequently [illegible] is thus in this small series of cases a net salvage of 4 patients, or 26.7 per cent.

SUMMARY OF RESULTS

	No of patients	Percentage
Total number operated on	15	
Operative deaths	3	20
Died from disease (2 years to 2 months after operation)	8	53 3
Alive, free from disease (2½ years to 10 months)	4	26 7

The importance of pelvic viscerectomy, however, cannot be measured solely by statistical assessment. The palliative value is considerable and in successful cases, life is not much worse than after excision of the rectum. Morbidity in successful cases is surprisingly small: the patients are fit to undertake normal household duties and enjoy a near-normal social life [illegible] modification controls fully the urinary fistula, and [illegible] 73).

The operation should be [illegible] ases, specially in uterine cancer in young patients and in post-radiation failures.

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POLIOMYELITIS

Part I

General

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Consultant Neurologist to United Oxford Hospitals

The viruses

The discovery by Enders (1951) of a method of growing the poliomyelitis viruses in tissue culture has greatly increased the prospects regarding practical benefits which may accrue from virus researches. The new methods have made it possible to carry out hundreds of experiments where formerly only a few were possible. It has now become possible to acquire information as to the distribution of the virus, and the immunological state of a sample community before, during and after an epidemic of poliomyelitis. It is generally thought that a high proportion of the adult population of most countries has sufficient antibody protection to prevent virus infection reaching the nervous system and causing paralysis. If this is so then there must be a great amount of subclinical infection which produces immunity but no recognizable illness.

A most important contribution to this problem has recently been reported by Melnick and Ledinko (1953). They point out that the numerical ratio of clinical cases to inapparent infections is basic to the understanding of the epidemiology of the disease. The roller tube cultures of the virus in monkey tissue has made it possible to demonstrate neutralizing antibodies quite easily in individuals. These workers therefore studied the development of neutralizing antibodies against 3 types of poliomyelitis virus in 200 children during a severe epidemic in North Carolina. This epidemic caused an incidence of recognized poliomyelitis of 62 per 100,000, the ratio of paralytic to non-paralytic cases being 2 to 1. None of the children tested developed a disease resembling poliomyelitis, and yet a large proportion of all age groups developed immunity. The previous epidemic in this area had been 4 years before, and this was reflected in the low incidence of immunity at the onset of the outbreak in the children under 4 years of age for types 1 and 3 which had been isolated from cases in the earlier outbreak. Newborn children were an exception where immunity to all 3 types of virus was found in 70 to 90 per cent of cases, a figure which presumably represented the maternal state. This early immunity had largely disappeared by the age of 6 months.

A high proportion of all age groups greatly increased their immunity to types 1 and 2 during the epidemic and it was possible from this to calculate directly the proportion of inapparent cases which occurred. This calculation indicated that under 1 year of age there were 175 inapparent infections for every clinical case. The corresponding figure for children of 1–2 years was 100; 3–4 years, 73; 5–9 years, 62; 10–14 years, 95.

Immunity to type 3 virus was unaffected in this epidemic as also was immunity to the Coxsackie, the influenza and the mumps viruses.

This study, which contains much other important material, is the first in which the ratio of subclinical to paralytic cases has been directly estimated. It fully supports the view that contact with the virus is very common, but few frank cases develop. Hence measures of isolation and quarantine are of limited value.

It is generally agreed that the virus spreads by close personal contact and that the virus may be conveyed by the naso-pharyngeal secretions or the stools. In Britain the current policy advises precautions to avoid spread of the virus as far as practicable. Recognized cases of poliomyelitis are generally isolated with "typhoid precautions" for 3 weeks after the onset of the major illness. The incubation period is thought to vary from 3 days to 5 weeks so that quarantine measures are difficult to apply. Nevertheless, quarantine of contacts for a period of 2 weeks may be advised

Active and passive immunity

As a large proportion of the population has immunity to the main types of virus, the use of gamma globulin has been explored, especially in the United States of America. This has been used to provide passive immunity for close contacts of cases, but as the effects last for only a few weeks, the usefulness of the method is limited.

However, the prospects for active immunity with a vaccine are promising, as it now seems probable that a safe method of using attenuated vaccine can be devised. The first attempts to use protective vaccines by Blanc and Martin (1953) and Koprowski *et al.* (1953) are being followed with close interest though the methods they are using are not fully acceptable to many virologists.

Paralysis

Whatever views may be held regarding the possibility of preventing people from coming in contact with the virus, it seems certain that many cases of infection with the virus never develop paralysis.

It has been established that infection often enters the body through the alimentary canal, a stage of viraemia has been recognized (Horstmann, 1952, 1953), and finally, in an unknown but small proportion of cases, the infection proceeds to the major illness with characteristic meningitic signs and symptoms. Even at this stage it is still uncertain as to whether or not paralysis will follow, for many patients after reaching this meningitic stage recover without experiencing any recognizable degree of paralysis.

In the frankly paralytic form of the disease paralysis appears at varying intervals after the development of the major illness (Russell, 1952). In roughly one quarter of paralytic cases, the paralysis appears on the first or second day, one quarter on the third day, one quarter on the fourth, and about one quarter at a later interval, the longest being about 2 weeks after the onset of meningitic symptoms.

When the paralysis actually appears, the meningitic symptoms may be subsiding, but this does not mean that the paralysis will be limited, and indeed some of the most disastrous cases behave in this disconcerting way. The paralysis, once it appears, may continue to spread for 2 to 5 days, and occasionally in the relapsing type, spreads in a second phase, usually 4 days after the first phase has ceased to spread.

FACTORS WHICH INFLUENCE SEVERITY AND TYPE OF PARALYSIS

In considering factors which may influence the clinical course of paralytic poliomyelitis, it should be appreciated that the fate of the nerve cells is probably decided within a few hours or days after the onset of the disease, and that during the pre-paralytic phase, many nerve cells must hang in the balance between life and death.

It is during the early hours of the major illness that physical rest seems most desirable (*see* Table I) and those who continue physical activity at this stage are most likely to develop severe paralysis (Russell, 1947, 1949; Horstmann, 1950). Tiring journeys in the pre-paralytic stage may also prejudice the survival of the motor cells, so there is much to be said for keeping the patients quietly at home until paralysis

becomes evident (Stimpson, 1952), provided of course that there is no possibility of a dangerous mistake in diagnosis being made. Patients who must always be transferred to hospital include those with paralysis of swallowing, with lung complications, with disturbance of consciousness, or with spreading paralysis which is likely to interfere with respiration.

TABLE I

THE EFFECT OF PHYSICAL ACTIVITY AFTER THE ONSET OF THE MAJOR ILLNESS ON THE DEVELOPMENT OF MODERATE OR SEVERE PARALYSIS

Dr Horstmann's cases	*Number developing paralysis (moderate, severe or fatal)*
174 patients rested on the first day of illness after onset of symptoms of major illness	62 (35 per cent)
173 patients did not rest on first day after onset of symptoms	133 (77 per cent)
Dr. W. R Russell's cases	
38 patients rested during the whole 24 hours following onset of major illness	8 (21 per cent)
51 patients did not rest during the whole 24 hours after onset	43 (84 per cent)

In order to assist physical relaxation and rest in the pre-paralytic phase, sedation with barbiturates is often helpful. It has even been maintained by Brehme and Leuterer (1953) that such heavy sedation (*Schlaftherapie*) prevents paralysis from developing. It should be pointed out, however, that barbiturates may be dangerous in some bulbar forms of the disease, and in such cases heavy sedation should only be used when there are facilities for establishing adequate artificial respiration without delay.

Inoculations

It has now been fully established (McCloskey, 1950, Hill and Knowelden, 1950) that an abnormally high proportion of children developing poliomyelitis develop the disease within 4 weeks of some form of inoculation or injection, and in this regard the prophylactic inoculation for diphtheria and whooping cough are specially suspect. Even injections of penicillin, however, seem to have contributed to the development of paralysis. In these cases paralysis is usually much more severe in the limb injected than elsewhere, and is indeed often confined to this limb.

Operations

Local operations are followed occasionally by paralytic poliomyelitis which shows predominant paralysis in that part of the body operated on. In this connexion an appreciable number of cases of bulbar poliomyelitis develop after tonsillectomy, so much so, that this operation is better postponed during epidemics.

DIFFERENTIAL DIAGNOSIS

The diagnosis of poliomyelitis virus infection can seldom be made with certainty until some lower motor neurone paralysis appears, and even then difficulties may arise.

The "major illness" (Horstmann, 1949), with its meningitic or pre-paralytic symptoms, is usually characterized by pains in the spine, limbs or trunk, and the pains may be severe or so slight that the patient attaches no importance to them. The spinal

pains may be referred to the cervical, dorsal, lumbar or sacral region, and may be so severe as to suggest local disease of the vertebrae. They may be so localized that the patient may report to the surgical out-patient department for x-ray examination of the spine. The chest or trunk pains may resemble those which occur in Bornholm disease or in acute abdominal diseases. The lumbar and sacral pains may have the characteristic feature that the patient cannot get comfortable in bed, and may sit in a chair all night, getting up to walk about from time to time in an attempt to get relief. The site of severe pain often corresponds to a section of the spinal cord which is severely affected by the virus.

Another remarkable feature of the spinal pains is that they may move from one site to another; for example, a lumbar or thigh pain may last for two days and then be replaced by pain in the neck or shoulder with a varying degree of overlap.

Retention of urine often precedes the development of paralysis, and drowsiness going on to stupor occurs in certain bulbar cases, especially in children.

The cerebrospinal fluid nearly always shows an increase in cells (both lymphocytes and polymorphs) during the early paralytic phase, but this soon changes to an increase of protein while the cell count returns to normal.

Some patients have such a severe cellular reaction in the cerebrospinal fluid as to suggest the diagnosis of meningococcal meningitis, while if the patient is unconscious the possibility of diseases such as virus encephalitis, cerebral abscess or tuberculous meningitis requires very careful consideration. The excellent results now possible in the treatment of tuberculous meningitis are only obtained if the correct diagnosis is made early, and this greatly increases the responsibility for accurate diagnosis in cases of intracranial infection.

The appearance of focal paralyses of spinal or cranial muscles often makes the diagnosis quite certain, but conditions such as Landry's paralysis, shoulder girdle neuritis (neuralgic amyotrophy), transverse myelitis, and hysterical paralysis, sometimes must have to be carefully kept in mind. During an epidemic, cases with paralysis from almost any cause may be sent to a hospital receiving poliomyelitis cases.

Muscular fasciculation appearing prior to paralysis is a highly characteristic sign. This is often an ominous indication that the fasciculating muscles will soon be paralysed but such paralysis will not always be very severe.

Most patients developing poliomyelitis remain fully conscious, and indeed, this preservation of normal consciousness often helps to exclude other possibilities. In some cases, however, the patient becomes drowsy and comatose; this is an important type of case, for contrary to the alarming impression of this critical illness, such patients (usually children) make a remarkably complete clinical recovery if they can be kept alive for the first two or three weeks of the disease.

Bulbar poliomyelitis

The term bulbar poliomyelitis is used in different ways. It can indicate perhaps that the eye movements, the muscles of mastication or of the face are affected, or that the breathing and blood pressure control are disturbed. It is perhaps expedient, however, from the clinical point of view to use the term bulbar poliomyelitis, especially for those patients, who, whatever other lesions occur, develop paralysis of the palate, pharynx or larynx. Paralysis of swallowing demands the introduction of a highly specialized form of treatment, and some convenient term is required which indicates the urgent need for special action in these cases.

It might have been anticipated that paralysis of swallowing would be easy to recognize clinically, but mistakes are all too frequent especially in children whose only obvious symptom may be a stubborn refusal to eat or drink. Drowsiness or coma may be associated with paralysis of swallowing, and when this occurs, the comatose state is the obvious feature, and the pool of mucus in the throat is thought to indicate

impending death, which indeed it does if the doctor fails to drain the pharynx and trachea by turning the child on his face, raising the foot of the bed and manually compressing the chest to assist expiration. It cannot be emphasized too strongly that it is extremely dangerous to nurse patients with paralysis of swallowing lying on their backs. They must be kept in the prone or semi-prone position for, apart from the danger of inhaling a pool of mucus, should the patient vomit, the inhalation of gastric contents is often fatal in its effects.

DEVELOPMENT OF PARALYSIS

It is a remarkable, if surprising, fact that severe limb paralysis may develop without being detected. Usually an adult draws attention to an inability to move, but an ill child does not describe his symptoms and paralysis may not be noticed until the patient gets up after an illness, or until respiration begins to fail.

The insidious development of respiratory paralysis may lead to some very confusing situations. The rapid respirations may lead to a diagnosis of pneumonia, and in some cases, atelectasis combined with paralysis of the intercostal muscles has led to severe collapse before the true state of affairs was recognized. True failure of respiration is easily recognized by watching the chest and abdominal movements, while the inadequacy of the tidal air is indicated by failure to count more than perhaps 1, 2, 3 to 10 in one breath. Loss of the power to cough is easily recognized and usually indicates paralysis of the abdominal muscles.

A remarkable proportion of intelligent adults think of poliomyelitis in connexion with their pre-paralytic symptoms, and if they confide their fears to a busy doctor they may sometimes provoke scepticism or worse from their medical adviser! Adults often become extremely anxious and panic-stricken as respiration becomes shallow, so much so that they are sometimes thought to be only hysterical.

ORGANIZATION OF POLIOMYELITIS UNIT FOR ACUTE CASES

It is now generally agreed that specially equipped units should be organized for the management of difficult cases of poliomyelitis. It may be at once admitted, however, that many cases of paralytic poliomyelitis need no very highly organized supervision in the acute stage of the disease; indeed, there are hospitals which provide neither physiotherapy nor special postural treatment in the acute stage of the disease, and in which the average case progresses satisfactorily.

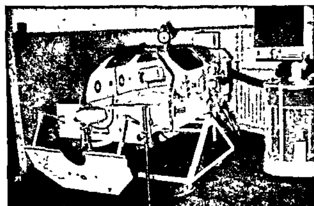
Nevertheless, in severe cases the need for specially organized treatment becomes very obvious. These special units are required to reduce the mortality as far as possible by concentrating their efforts on the critical cases. The chief concern of these units is first to keep all the airways clear, and secondly if necessary, to establish and maintain artificial respiration in the way which is most appropriate to the case.

The actual personnel required for the unit may be enrolled from various forms of specialists, but those concerned should be prepared to make a special study of the problems. Thoracic anaesthetists have made a special contribution to the problems which arise, and it is important that provision for bronchoscopy and tracheotomy should always be available at very short notice.

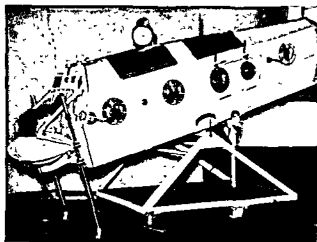
There are difficulties in operating these units efficiently. The key personnel must always be available to "go into action" at very short notice, and if necessary should be prepared to act as a mobile team to move cases to the special centre. At least [illegible]

the nurse throughout the twenty-four hours, and this service is very difficult to

These frequent changes of posture must take precedence over other considerations during the acute stage, as they provide a vital defence against atelectasis. Here it may be mentioned that changes of posture may have surprising effects on breathing in cases of partial paralysis. For example, when the intercostal muscles and abdominal muscles are paralysed the movements of the diaphragm provide an adequate degree of inspiration, but in order to provide for expiration the foot of the bed must be raised so that the weight of the abdominal viscera provide some expiratory force. This is fortunate, for this posture also assists gravitational drainage of the pharynx and trachea. In general, therefore, there should be no pillows and lying on the back should be avoided as far as possible.



(*a*)



(*b*)

FIG 75.—(*a*) Respirator with "split front" manufactured by Siebe Gorman, Ltd.; (*b*) patient in semi-prone posture and tilted for drainage purposes

Failing respiration

Not long ago the usual practice regarding respiratory failure was to wait until the patient was severely anoxic before using a respirator. This attitude, however, increases the danger of atelectasis and is inconsistent with the general attempt to rest muscles during the acute stage of the disease. There is, therefore, much to be said for early respirator treatment before the patient becomes seriously embarrassed, but such treatment should be provided by nurses trained to transfer a patient into a respirator without inflicting either physical or psychological trauma. It has been mentioned that two special nurses may be required for one patient, but to put a patient in a respirator, three or four additional people may be required when the patient's position requires to be changed. The new Siebe Gorman respirator (Fig. 75) with split front considerably simplifies the nursing care of respirator cases.

The detailed care of respirator cases from the nursing point of view has been described in publications of the National Foundation for Infantile Paralysis, U.S.A. (1948).

The following points require special attention.

(1) Correct adjustment of operating pressures. While the lungs are healthy, hyperventilation may easily be produced. Pressure of about minus 16 centimetres and plus 5 centimetres of water at a rate of 16 cycles per minute are often suitable for older children and adults, provided the lungs are reasonably healthy. When one lung is collapsed, a much higher rate may be required, up to 35 cycles per minute, and even higher in infants.

(2) The airways must be kept clear by suction and posturing. Frequent changes of position, including the semi-prone posture, can be obtained in the newer respirators and are highly advantageous. The breath sounds at the larynx should be frequently listened to in order that pooling of secretions may be recognized in time. The nurse may use a stethoscope for this but a throat microphone (such as may be obtained from Isis Equipments) amplified by a loud speaker is greatly preferable (Stott, 1953).

(3) The adequacy of oxygenation may be checked by an Oximeter (Stanley Cox, Ltd.), but frequent blood pressure readings should also be taken as a rise of blood pressure is an early sign of CO_2 retention.

(4) Every precaution should always be taken to avoid atelectasis, and daily lung x-rays may be desirable. Bronchoscopy may be required, while any loss of functioning lung tissue may necessitate increasing the pressures and rate at which the respirator is working.

(5) A good respirator is so constructed that most nursing can be carried on without opening the respirator, but in addition it is essential that an efficient form of positive pressure breathing be available to keep the patient comfortable when the respirator is opened. The Oxford Inflating Bellows (Macintosh, 1953) is convenient for this purpose (*see* Fig. 74) and, if operated by hand, can be made to synchronize with the rhythm of the respirator before the machine is opened. Mechanically operated respiration pumps may be very useful and are referred to later (p. 157).

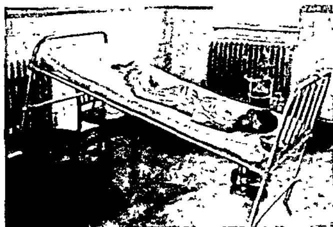


FIG. 76—Postural drainage in semi-prone posture.

CARE OF PHARYNGEAL PARALYSIS

Many cases of bulbar poliomyelitis have little or no paralysis of the limbs or trunk while paralysis of the pharynx rapidly leads to a most dangerous situation. These patients often recover completely if they can be kept alive for the period of dysphagia which may last for from three to fourteen days (occasionally for a longer period).

No effort therefore should be spared to save these patients from their dangerous predicament. The immediate allocation of specially trained nurses saves many lives

in this group. Careful posturing is vitally important and should be instituted in the home or ambulance as soon as the dangers of inhalation are recognized. Often these cases are children, who, if left unattended, will sit up and inhale vomit; this sometimes leads to fatal collapse.

Nursing on the back is always dangerous in bulbar cases unless the bed is tipped very steeply. The patient should have a firm mattress with no pillow and be turned on his face or semi-prone. Raising the foot of the bed 18 inches (Fig. 76) is a most valuable addition from time to time to facilitate drainage. Inverted "V" beds are specially useful (Fig. 77). The lateral posture may also be used, and the tilted posture may be relaxed for nursing or other reasons, provided it can be re-established within a second or two should the child, for example, vomit unexpectedly or choke while attempting to swallow. A simple harness around the child's shoulders and secured to the foot of the bed prevents him sliding out of position when the bed is steeply tilted.



FIG. 77.—Adjustable inverted "v" bed generally suitable for the prone or semi-prone posture, but here used for a posture which is almost lateral The child is wearing a throat microphone which leads to a loud speaker.

During the period of pharyngeal paralysis the patient's every breath should be listened to preferably with the assistance of a throat microphone, so that any accumulation of secretions in the upper air passages may be promptly recognized, and so that irregularity or failure of respiration or retching may also be observed quickly. The nurse can herself deal with minor accumulations of secretions by increasing the tilt of postural drainage and using the sucker. However, she should also have immediate access to a doctor versed in the methods of aspirating the trachea, and there should be quick access also to one who can perform the operations of bronchoscopy, laryngeal intubation or tracheotomy

As has already been mentioned, many bulbar cases retain adequate strength in the respiratory muscles, but careful watch must be kept not only for weakening of the respiratory muscles, but also for failure of the respiratory centre to maintain the regular respiratory rhythm. In cases with respiratory weakness the development of atelectasis may immediately precipitate a crisis as the muscles may at once become inadequate for the reduced available lung tissue. Any of these developments may require the use of artificial respiration, but the point at which this becomes necessary is difficult to recognize The difficulty is greatest when the patient's consciousness is clouded, as there are then inevitable doubts as to whether the mental dulling is due to cerebral hypoxia or to the focal effect of the virus on brain-stem centres. Anxiety in these cases is increased by the knowledge that the use of a respirator in the presence of pharyngeal paralysis is most hazardous owing to the danger of the machine sucking secretions into the lungs

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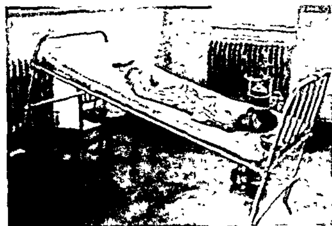


FIG 76.—Postural drainage in semi-prone posture.

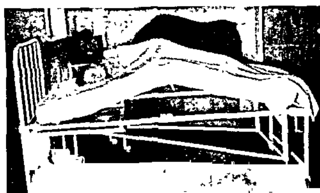
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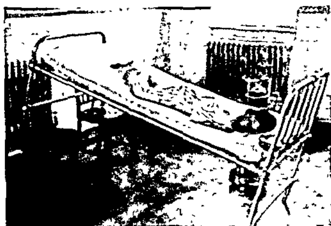


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RESPIRATORY FAILURE COMBINED WITH PHARYNGEAL PARALYSI

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Such patients may sometimes be handled successfully in the modern respirators when it is possible to nurse patients in the prone or semi-prone posture (Fig. 75), and to tilt the respirator as required to assist the drainage of secretions from the upper air passages, but many difficulties may arise, and even a slight accumulation of secretions in the airways may quickly lead to a hopeless situation.

Tracheotomy may be done in a tank respirator, but exceptional nursing difficulties arise in the care of a tracheotomy tube in a respirator for it then becomes almost impossible to continue the frequent changes of posture which are desirable from the point of view of the lungs. However, many American clinics practise tracheotomy in respirator cases with paralysis of swallowing or obstructed airways, and depend on suckers and tilting of the respirator to obtain proper drainage. The use of a high positive pressure phase in the respirator is helpful in this type of case.

THE COPENHAGEN METHOD

Professor Lassen (1953) and Dr. Ebsen evolved in Copenhagen, during the grave outbreak of 1952, a method of controlled respiration for cases developing respiratory insufficiency which is similar to that used by anaesthetists to maintain breathing when the muscles are curarized. After preliminary intubation of the larynx a high tracheotomy was performed, and a wide cuffed tracheotomy tube inserted to prevent the aspiration of pharyngeal contents. Positive pressure breathing was then maintained through the tracheotomy tube for as long as respiration remained inadequate. The positive pressure was provided as in anaesthesia by briskly squeezing an anaesthetic bag to synchronize with the patient's own inadequate effort, and medical students were trained to do this in eight-hour shifts.

Professor Lassen used this method freely for all cases of respiratory difficulty so that he was able to dispense with the use of tank respirators almost entirely. He used a CO_2 absorption method in a semi-closed circuit, but the present tendency is to prefer open circuits which remove the need for CO_2 absorption.

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Frequent changes of trunk posture assisted drainage.

tube, while preventing the passage of secretions downwards, also rendered it essential that all secretions spreading upwards from the bronchi should be removed by frequent suction. This must be done quickly in order to reduce the period of interfering with respiration. The same difficulty arises when bronchoscopy is required, as artificial respiration must not be interrupted for more than a short time in severe cases. The need for suction is specially apparent after changes of posture and after vigorous pressure-vibration (Fig. 78) to the chest by physiotherapists. The collection of secretions in the trachea and bronchi can be recognized by listening with a stethoscope over the tracheotomy tube cork.

A fine plastic oesophageal catheter is passed *via* the nose into the stomach in order to relieve gastric distension and to provide adequate nourishment.

Mechanical respirator pumps for positive pressure breathing

During the Copenhagen epidemic Lassen trained over 1,000 medical students in the technique of bag ventilation. Various methods have been designed to provide a "mechanical student". Pressure-controlled electrical devices have been used, the cycling of which depends on the height of intra-pulmonary pressure (Bang, 1953). This method is in some ways the best, as the machine should synchronize with the patient's natural efforts, but the intra-pulmonary pressure of air is always positive and rises to considerable heights. Further, the absence of a phase of negative or zero intra-thoracic pressure is thought to interfere with the return of blood to the heart.



FIG 78—Pressure-vibration to chest of a patient still with a tracheotomy tube after weaning from 4 weeks of positive pressure respiration. The disease in this case was acute infective polyneuritis

An alternative, and probably preferable, method is to pump air or oxygen (or both) into the lungs by a pump for which there is full control of maximum pressure, rate and volume. Thus a volume of 500 millilitres (actually reaching the lung) at 16 per minute, and a maximum pressure of 15–20 centimetres of water is adequate for an average adult with healthy lungs. Figs 74 and 79 illustrate pumps designed by Russell and Schuster (1953) which have been found satisfactory in practice. A feature of these machines (H. G. East & Co.) is that the pressure of delivery is determined simply by the gravitational effect of a weight which is adjusted according to the

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Fig. 78. Pressure [illegible] to chest of [illegible]

intra-thoracic pressure is thought to interfere with the return of blood to the heart.

An alternative, and probably preferable, method is to pump air or oxygen (or both) into the lungs by a pump for which there is full control of maximum pressure, rate and volume. Thus a volume of 500 millilitres (actually reaching the lung) at 16 per minute, and a maximum pressure of 15–20 centimetres of water is adequate for an average adult with healthy lungs. Figs 74 and 79 illustrate pumps designed by Russell and Schuster (1953) which have been found satisfactory in practice. A feature of these machines (H. G. East & Co.) is that the pressure of delivery is determined simply by the gravitational effect of a weight which is adjusted according to the

pressure desired. The volume and speed are also controlled through a wide range.

Machines of this type require to use an expiratory valve which allows free expiration for a period slightly longer than the inspiratory phase. There are several possible types of expiratory valves available; that designed by Stott (Messrs. Owen Mumford) is simple and satisfactory with very low resistance, but it requires to be changed every 3 or 4 hours for cleaning.

The air or oxygen delivered to the patient requires to be saturated with moisture, hence a good humidifier is essential (Fig. 79) as has been described by Marshall and Spalding (1953).

In our experience of several cases treated by this method these machines are adequate for many cases, but might possibly benefit from the introduction of a suck phase during expiration in order to assist the flow of venous blood into the lung. Many cases are so complicated by severe lung collapse by the time they reach hospital, that every effort should be made to design the best possible machine, as even a slight improvement in action might turn the scales in a difficult case.

Air alone is often suitable for use in such machines, but oxygen added or alone can be given as required by the patient's blood chemistry.

Management of cases of poliomyelitis receiving positive pressure artificial respiration

The aim of all methods of artificial respiration must be to keep the patient as nearly as possible in the normal physiological state, not only as regards oxygen uptake but also as regards carbon dioxide excretion. It is often possible to judge satisfactorily of oxygenation on clinical grounds or with the aid of an oximeter reading from the lobe of the ear, but in cases of special difficulty, for instance when there is a considerable amount of pulmonary collapse, it may be necessary to estimate the oxygen content of blood obtained by arterial puncture. The level of arterial carbon dioxide is much more difficult to assess, and adequate oxygenation gives no guarantee that carbon dioxide excretion is neither excessive nor inadequate. For example, one of the disadvantages of using oxygen instead of air for ventilation (though this may be necessary) is that it is possible to maintain good oxygenation with pure oxygen while providing totally inadequate ventilation for excretion of carbon dioxide.

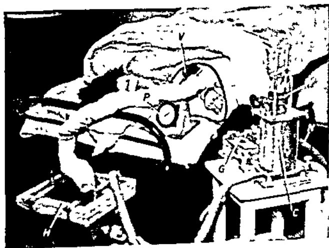


FIG 79—Positive pressure respiration *via* a cuffed tracheotomy tube (*see* text). Patient required this form of respiration for 2 weeks before natural breathing returned. W, weight operating piston in cylinder (c); G, motor operating valves; H, humidifier; V, expiratory valve (Stott); P, pressure gauge; N, lead from hospital suction system which operates this type of pump.

It is important, therefore, to keep in mind the principal clinical signs of carbon ... a rising blood pressure and sometimes a rising pulse. ... is being underventi- ... bon dioxide, respiratory alkalosis cannot be diagnosed certainly at the ... and, while the most

satisfactory way to control the ventilation rate is no doubt to estimate the partial pressure of carbon dioxide in samples of air taken from the carina, facilities for this analysis are not readily available. Frequent estimation of the *p*H of freshly passed urine, provided it is not infected, gives a guide which can be checked by estimating blood electrolytes, especially serum sodium, plasma chloride, and plasma bicarbonate. In respiratory alkalosis the difference, in milliequivalents per litre, between the serum sodium and the sum of the plasma chloride and plasma bicarbonate exceeds the normal figure of 12, due to a fall in the bicarbonate.

Pulmonary infection and collapse are a constant danger, and frequent clinical and radiographic examinations are necessary to detect them without delay. If any rise occurs in the pressure required to provide ventilation, as indicated by the pressure gauge (Fig. 79), the possibility of pulmonary collapse must at once be excluded. Vigorous physiotherapy to the chest, accompanied by thorough aspiration of secretions with a soft rubber catheter or a Tiemann's catheter, will frequently clear an occluded bronchus, but bronchoscopy should be performed without hesitation when required.

Nursing

The patient should be nursed on a sponge-rubber mattress on a bed that can rapidly be tipped (Fig. 74). If the head of the bed is not removable, the patient should be placed with his head at the foot of the bed. He should be nursed in the lateral and semi-prone positions, and to avoid pressure sores and to minimize pulmonary complications, it is essential that he should be turned every two hours. In addition to the usual pressure areas, special attention should be paid to the skin over the acromio-clavicular joint which the head-down position renders vulnerable.

Physiotherapy

Chest.—Since the patient cannot cough, a physiotherapist should give pressure-vibration to the chest to clear secretions from the lungs. To treat the lower lobes, this must be done with the patient tipped head down 15°–20° (Fig. 78). Secretions will appear, and must be aspirated during this treatment, and also immediately before and after the patient is turned. Physiotherapy every four hours may be desirable, especially if pulmonary complications develop All joints should be moved through a tolerable range of passive movement from an early stage.

Feeding

Since a cuffed tracheal tube prevents vomit entering the bronchial tree, it is safe to feed the patient by a polythene tube passed through the nose into the stomach. At first, four-hourly feeds of 4 ounces each (milk 2 ounces, Ringer's Solution 1 ounce, water 1 ounce, glucose 2 level teaspoonfuls) are given, and, if the stomach is empty before each feed, indicating that the feeds are being absorbed, feeding can be every two hours with 8 ounces of the same mixture. If the blood urea is normal a balanced diet containing some protein can be substituted. This may cause a temporary rise in blood urea, and when normal levels are again reached, a diet with a higher protein and calorific content can be adopted. These feeds are diluted with Ringer's Solution and water to provide as much chloride potassium and hydration as biochemical investigations indicate are required.

Antibiotics

Penicillin, 1,000,000 units twice daily, may be given as a routine, and other antibiotics as required.

Assessment of the value of the Copenhagen method

Experience of positive pressure ventilation as far as our Oxford Unit is concerned (Crampton-Smith, *et al.*, 1954) depends on a study of 4 cases, 3 of which survived.

The survivors required positive pressure breathing for 4 weeks, 2 weeks, and 3 weeks respectively. The first 2 proved to be Landry's paralysis and made a complete recovery; the third survivor also had serious limb paralysis and had paralysis of swallowing with his lungs full of inhaled secretions on admission.

We were satisfied that these 3 cases could not have been kept alive in our hands by any other method, and now incline to the view that the Copenhagen method should be used without hesitation in cases of pharyngeal paralysis with respiratory insufficiency due to either paralysis of respiratory muscles or to the development of lung complications. Clearly, therefore, this method should be available in the special centres.

It should, however, be made perfectly clear that the Copenhagen method is most dangerous in the absence of close and experienced nursing and medical supervision, and we have found that an experienced doctor must be at hand day and night during the early critical days. This method solves some problems, but introduces others and greatly increases the number of things that can go wrong. For example, any of the following may happen.

(1) Undetected secretions may accumulate in the trachea and bronchi to a dangerous degree.

(2) The pump pressure may suddenly fail owing to a kink in the tube or a connexion blowing off or a failure in the pump.

(3) The expiratory valve might fail to operate so that the chest becomes progressively inflated.

In addition to such mechanical faults, sudden changes in the blood pressure or consciousness may indicate that something is going wrong.

[illegible] that the Copenhagen method is most valuable [illegible] intubation and hand-operated positive-pressure inflation

CONCLUSION

The theme of this article is that a concerted effort should be made to reduce the present high mortality rate in acute poliomyelitis. There are several ways in which considerable success in this direction can be achieved. Many patients with pure bulbar paralysis whose lives are saved by modern principles will make a complete recovery, and generally the end result will be so good that the great effort involved has obviously been well worth while.

The special units required to handle the special cases require careful planning in advance so that the unexpected case can be dealt with efficiently. Two of the worst cases seen in the past year became critically ill, one on Christmas Eve and the other on the Saturday of the August Bank Holiday.

(*See also British Surgical Practice*: Poliomyelitis, vol 7, page 94, S Key 274)

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PART II

TREATMENT OF POLIOMYELITIS

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PATHOLOGY IN RELATION TO TREATMENT

Changes in the central nervous system

When the spinal cord is invaded by the virus of poliomyelitis the changes that take place occur with great rapidity. The damage to the anterior horn cells reaches its peak within a few days (Bodian, 1949), and thereafter the process is one of recovery and the clearing away of such anterior horn cells as have been completely destroyed. Phagocytosis of dead neurones begins as soon as the fate of these cells is sealed and thus the invasion of the cord by the virus is quickly followed by a brisk non-specific inflammatory reaction. Because there is as yet no known means of arresting the destruction of neurones the interest of the clinician is centred on those that survive. The most striking change in these cells is loss of their Nissl granules and Bodian has shown (chiefly in the rhesus monkey) that the restoration of normal histological structure takes about thirty-five days. The ultimate pattern of paralysis is usually determined before the end of the first week and by the end of the fifth week the stage is set for making the best use of such neurones as have been spared. Yet, although there is no doubt about the first of these conclusions, Einarson (1949) has shown that in man a certain (but unspecified) proportion of anterior horn cells remain morphologically abnormal for three months or even for as long as eight months after the onset of paralysis, cells which he believes are still capable of recovery. So far, we ourselves (Sharrard; unpublished work) have been unable to confirm Einarson's observations. Nevertheless, there may be a border-line group of cells whose state might be unfavourably influenced by active treatment such as would be appropriate for most of the survivors.

Axonal changes

The axons of cells that have been destroyed undergo Wallerian degeneration and disappear. The electrical reactions of affected muscles and the electrical excitability of accessible nerve trunks in poliomyelitis (Brooks, 1953) indicate that the axons of cells that have been damaged, but are capable of survival, do not usually degenerate, though Brooks has suggested that there may be a short terminal zone of Wallerian degeneration in the axons of some of these cells. However, there is no evidence whatever of extensive axonal degeneration, followed by regeneration, such as occurs after peripheral nerve injury.

This has a bearing on treatment. After nerve injury, where there is some prospect of motor recovery, it is important to maintain denervated muscle in a state as near normal as possible by regular and powerful stimulation with currents of long duration (Jackson, 1945; Seddon, 1949). Axonal degeneration in poliomyelitis is an expression of *neuronal destruction* and there is, therefore, no rational basis for electrotherapy designed to maintain muscle volume and to prevent the interstitial changes consequent

...rward the interesting hypothesis that part of the
...the outgrowth of sprouts from the terminations of

normal axons in a partially paralysed muscle which form functional connexions with the muscle fibres of neighbouring motor units whose neurones have been completely destroyed. Hoffman's (1950), and Morris's (1953) histological evidence goes some way towards establishing the actuality of this mechanism.

Changes in muscle

No specific changes have been described in voluntary muscle. Fibres that have been denervated shrink progressively and there is a slowly increasing interstitial fibrosis with, much later, deposition of fat.



(a)



(b)

Fig. 80.—(*a*) Severe deformity of the upper limb; (*b*) severe deformity of the lower limb.

Sensory and irritative phenomena

Although poliomyelitis is predominantly an affection of motor neurones, its sensory and irritative manifestations cannot be ignored. In the early stages of the disease,

spinal rigidity is commonplace. In addition there is often spontaneous pain in the trunk and limbs, tenderness of muscles, sometimes pain when an attempt is made to stretch them, and occasionally true muscle spasm. Cutaneous hyperaesthesia is exceptional and loss of cutaneous sensibility very rare. It has not yet been possible accurately to correlate these phenomena with the known histological changes. Lesions in the posterior root ganglia are almost invariable; similar damage has also been seen



FIG. 81.—Irreversible oedema of the legs in a severely paralysed patient where early treatment had been inadequate.



FIG 82.—Fixed deformity of the fingers due largely to contracture in the completely paralysed long extensor muscles; aggravated by careless splinting and neglect of passive movements

in the posterior horns. As there are no changes in muscles to account either for the tenderness they sometimes exhibit or for the pain on stretching and spasm, to which attention has been drawn increasingly in recent years, the cause of these phenomena must be sought within the central nervous system. It is possible that they are due to the lesions in the cord already mentioned. However, it may well be that the changes

that have been found in the hypothalamus and brain stem, so well summarized by Bodian (1952), and occurring even in cases of purely spinal paralysis, are responsible for some of the non-paralytic manifestations of the disease; on the motor side, the early transient increase in deep reflexes and the irritative changes in muscle; the almost invariable pyrexia; and the remarkable though clinically latent disorders of vasomotor control (McPherson and Kessel, 1954).

Deformity

As a cause of deformity, poliomyelitis (Fig. 80) is rivalled only by rheumatoid arthritis and we may briefly review as follows what is known of the pathology of contractures of muscle and their fascial envelopes, which are the precursors of deformity.

(1) *Oedema.*—The return flow of blood and lymph from a limb depends largely on muscular activity and if a paralysed part is not elevated it becomes swollen. After a time a cobweb-like deposition of collagen takes place in the oedema fluid which results in stiffness of all the soft tissues, muscles, tendon sheaths, subcutaneous tissues and even skin (Fig. 81)

(2) *Active muscle.*—A normal or moderately weak muscle whose antagonist is completely paralysed will tend to shorten, and this is a common cause of deformity in the neglected case.

(3) *Paralysed muscle.*—The interstitial fibrosis that develops in partially or completely denervated muscle may lead to contracture if the part is immobilized in such a way as to relax the affected muscle. This is the chief cause of contracture in cases where splinting has been applied injudiciously (Fig. 82). These second and third causes of contracture are, of course, mutually exclusive in any one part of the body, though both may be operative in different parts of the same patient.

(4) *Ligaments and capsules of joints.*—A contracture that starts in muscle leads inevitably to capsular and ligamentous changes in the relevant joint, shortening of the



FIG. 83 —Subluxation of the hips in a child A change from long to short leg appliance had been made too early.





FIG. 84.—Calcaneo-cavus deformity due to weakness of the calf muscle, a condition that may be prevented by early tendon transplantation.

[illegible]

the normal length of muscles, whether paralysed or active, a disturbance of balance between opposing muscle groups leads to an abnormality of posture that will tend to cause a fixed deformity sooner or later (Fig. 84) and, in children, gross distortion of bones and joints.

(6) *Gravity: body weight.*—In a child any part of the body that bears weight is likely to become deformed if the support of the muscles controlling it is defective. There need be no asymmetry of muscle pull and indeed, the part may be completely paralysed. The weight of the body alone will lead to the development of ligamentous laxity, alterations in the shape of the surfaces of joints, and finally, bony deformity.

(7) *Early contractures.*—These are mentioned last because their cause is unknown. A muscle, and especially one that has been painful, may become shortened within a few

weeks, long before the interstitial fibrosis due to denervation has become significant.

Recovery

Several observers have produced graphs showing the general progress of recovery

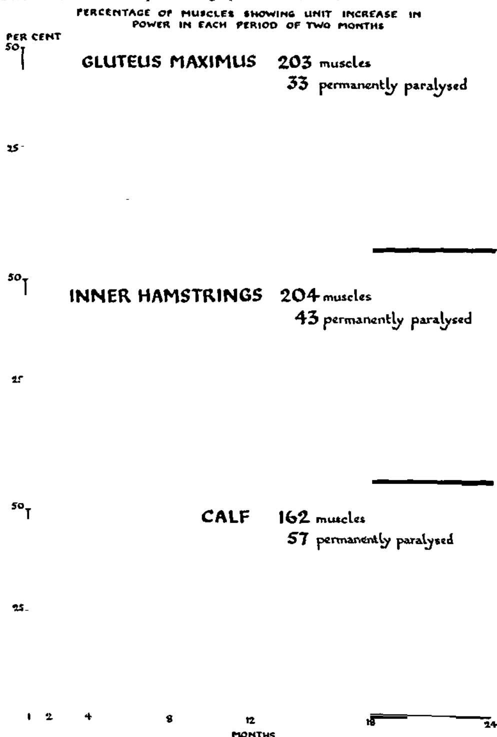


FIG. 85—The general pattern of recovery (after Sharrard). Although some muscles are more liable than others to suffer permanent paralysis the progress of recovery is much the same in all.

(Harry, 1938; Green, 1949; Lenhard, 1950; and Sharrard, unpublished work), which all follow the same pattern. The most informative are Sharrard's (Fig. 85), which indicate that the process is much the same in all muscle groups irrespective of their distance from the spinal cord. The greater part of the recovery occurs early and this, together with the lack of significance of the distance of a muscle from the cord, is conclusive evidence against recovery by axonal regeneration.

It is, however, hardly possible to explain recovery entirely in terms of the resumption of activity by the anterior horn cells that have suffered reversible damage, although this must account for the chief wave of recovery, which occurs early and often before any active treatment has been given. If the surviving anterior horn cells regain their normal structure by the fifth week after the onset of paralysis, it might reasonably be expected that functional recovery would follow soon after. Yet we sometimes observe a significant increase in power between the third and tenth months. This might be due to recovery in cells, such as Einarson has described, which remained structurally abnormal for longer than the usual 35 days; but it seems improbable that neurones of this kind are numerous. A more likely explanation is that so well presented by Bodian who, in this connexion, has drawn attention to the probable significance of the widespread lesions that occur in the brain stem, in the intermediate zone of the



FIG 86—Enormous hypertrophy of the great glutei in a patient with paralysis of both quadriceps.

spinal cord and, to a lesser extent, in the precentral area of the cerebral cortex. Paralysis persisting for several months might well be due to the interruption of motor tracts above the level of the lower motor neurone, and recovery would be due to the development of new functional pathways. This process must take time and be greatly facilitated by active re-education. If this reasonable hypothesis is correct, then re-education is a significant factor in hastening the return of voluntary power. Weiss's hypothesis may be relevant too, though his experimental work suggests that axonal sprouting is an early phenomenon. It is noteworthy too that the earliest wave of recovery, that due to the return of function in the anterior horn cells, is by no means invariably followed by recovery in the third to the tenth months and in this case it may be presumed that the lesions are largely confined to the anterior horn cells.

Some of the late recovery is due to the hypertrophy of surviving muscle fibres.

Muscle hypertrophy of an astonishing degree can occur spontaneously in the victims of poliomyelitis though it is most apparent in muscles that have been affected little, if at all (Fig. 86). DeLorme and Watkins (1951) have shown that it can be induced in paretic muscles by vigorous exercise, and histological preparations sometimes reveal abnormally large muscle fibres (Wohlfahrt, 1952; Sissons, unpublished work).

PROGNOSIS

Sharrard's figures (Fig. 85) show that some muscles are more likely than others to remain completely paralysed. He has found (unpublished work) that this is due to the topographical arrangement of the anterior horn cells connected with various muscles. Some have cell stations extending over a number of segments; others, such as the deltoid and tibialis anterior, have short ones which are therefore more liable to total destruction where the damage is intense, but extends over only a limited zone. Thus the prognosis for recovery varies from muscle to muscle, although as already mentioned, the process of recovery, when it occurs, does not vary.

In the study of the individual case the muscle charts (Fig. 87) are invaluable. If there is no return of power in a muscle within six months from the onset, the paralysis is permanent and nothing will be gained by continuing the treatment for that muscle. If one segment of a limb or the whole of a limb is still completely paralysed after three months the outlook is bad and, again, treatment should be discontinued; the damage to the anterior cell columns has been overwhelming. Brooks (1953) has shown that the electrical reactions of muscle and the electrical excitability of accessible peripheral nerve trunks give reliable prognostic information rather earlier than do muscle charts, though it is hardly practicable or necessary to use this form of examination routinely.

Although the prognosis should never be concealed from the patient's relatives, whose responsibilities may be considerable when he leaves hospital, it is wise to avoid making a gloomy forecast in the hearing of the patient himself. He is likely to need much courage and determination to make good use of such power as is left to him. At first he is conscious chiefly of what he has lost, and to be told that there is no prospect of his being able to resume a promising career or to indulge in a favourite sport may wreck his morale. In the friendly intimacy of a well-conducted orthopaedic ward he gradually comes to understand what are his own prospects of recovery; the memory of his former fitness becomes less painfully sharp, he hears about the plans of others whose treatment is more advanced than his own, and comes to realize that he, too, must find out how to "strengthen the things that remain".

TREATMENT

It is still unfortunately necessary to insist on muscle charts (Fig. 87) being kept; whatever reasons may be advanced against these records the underlying objection is to the labour they entail The muscle chart is the indispensable guide to treatment. If a clinician lacks the patience needed for this work it is doubtful if he should be treating cases of poliomyelitis. However, provided she is well-trained and capable of being objective, it is permissible to delegate much of the routine recording to a physiotherapist.

The examination of the motor system required to establish the diagnosis should be minimal, the limbs will almost certainly be painful and the patient cannot tolerate an exhausting examination. However, towards the end of the first week the clinician should begin to make a detailed record of the extent and also of the gravity of the paralysis. It is often wise to spread the examination over a few days in order to spare the patient fatigue and, with a child, to gain its confidence. At the same time the presence of sensory disturbances, such as muscle tenderness and pain on particular movements, will be recorded.

Name.................................... Ward .... Record No. . . .

Examiner .... Date. ....

LOWER LIMB

	Right	Left
Date		
Hip flexors		
Hip extensors		
Abductors		
Adductors		
External rotators		
Internal rotators		
Extension of knee		
Quadriceps		
Flexion of knee		
Inner hamstrings		
Outer hamstrings		
Dorsiflexion of foot		
Tib. ant		
E.C.D.		
E.H L.		
Plantarflexion of foot		
Calf		
F.D L.		
F.H L		
Intrinsic muscles		
Eversion of foot		
Peroneus L		
Peroneus B		
Inversion of foot		
Tib post.		

SHOULDER GIRDLE

	Right	Left
Date		
Elevation of scapula		
Trapezius		
Levator scapulae		
Int rotation of arm		
Adduction of arm		
Pectoralis major		
Teres major		
Latiss dorsi		
External rotation of arm		
Abduction of arm		
Spinati		
Deltoid		

NECK AND TRUNK

Flexion of neck	
Sterno-mastoid	
Ant cervical	
Platysma	
Extension of neck	
Extension of trunk	
Post. cervical	
Thoracic erector spinae	
Lumbar erector spinae	
Forward flexion of trunk	
Rectus abdominus	
Obliques	
Lateral flexion of trunk	
Quadratus lumborum	

Early treatment

At this early stage four kinds of treatment are required.

(1) The relief of pain. This, alas, is still empirical. Provided there is no threat of paralysis of breathing or swallowing there is no objection to the use of sedatives and, if necessary, of fairly potent analgesics. Even in the absence of pain the patient will be grateful for a drug that takes the edge off his sharp consciousness, and it should not be withheld. If it is found that passive movements provoke pain and that a full range is limited by pain on stretching muscle the local application of heat is valuable. Although radiant heat from a cradle or an infra-red lamp is easy to apply, the hot pack first used by Lovett and popularized by Elizabeth Kenny is more effective. The procedure is as follows.

A double layer of thick woollen material, large enough to envelop the affected part,

FOREARM AND HAND

	RIGHT	LEFT
DATE		
Extension of forearm		
Triceps		
Flexion of forearm		
Brachialis		
Brachioradialis		
Biceps		
Supination of forearm		
Supinator		
Pronation of forearm		
Pronator teres		
Pronator quadratus		
Extension of wrist		
E.C R L		
E.C R B		
E.C U		
Extension of digits		
E.C D		
E.P L.		
E P B		
E I		
Flexion of wrist		
F C.R		
P L.		
F C U		
Flexion of digits		
F D P		
F D S		
F P L		
Opposition of thumb		
A P L.		
A P B		
F P B		
O P		
Mass intrinsic action		
D I 1, 2, 3 and 4		
P I 1, 2 and 3		
Hypothenar muscles		
Adductor pollicis		

FIG. 87—Muscle charts devised by D. M. Brooks and used at the Royal National Orthopaedic Hospital The power of muscles is recorded in accordance with the grading approved by the Nerve Injuries Committee of the Medical Research Council. (5) Contraction against powerful resistance. (4) Contraction against gravity and some resistance. (3) Contraction against gravity only (2) Movement only with gravity eliminated. (1) Flicker of contraction (0) Complete paralysis.

is soaked in very hot water, passed rapidly through a wringer to express as much moisture as possible, then wrapped round the limb and covered first with thin mackintosh or oiled silk and finally with two layers of any insulating fabric. (For further details *see* Pohl and Kenny, 1949.) If this technique disturbs the patient unduly, the pack, with its coverings, may be simply laid on the painful part. Three or four packs a day should be used and the patient should not be disturbed during his sleeping hours. A useful alternative suitable for children who can be conveniently handled is immersion in an ordinary bath of water at 93°–98°. The advantage here is that as the pain subsides, passive movements can be carried out most conveniently in the water. Short-wave diathermy is dangerous, at any rate in children. Its continued application can arrest epiphyseal growth (Wise and Watkins, 1949; Compere, 1949).

Yet, heat, valuable as it is, will not invariably relieve pain and stiffness. If these irritative phenomena persist for more than five weeks it may be worth trying the action of methonium compounds (Lannon and Braudo, 1949) which, like Novocain injected into the lumbar sympathetic ganglia (Collins, Foster and West, 1947) for pain limited to the lower limbs, are said to give dramatic relief. However, the writer's experience is limited to so few cases that he cannot commend such treatment from personal knowledge.

Fortunately, in all but a few cases the painful manifestations of poliomyelitis are either so slight or clear up so quickly as not to present a serious problem.

(2) Elevation of the paralysed part prevents oedema and the stiffness consequent on it. For the lower limb, the recumbent position suffices; for a completely paralysed upper limb, pillows or slings are adequate though an abduction splint is useful if the patient is fit to get up after a few weeks. The tendency to oedema usually diminishes in two to three months.

(3) Passive movements. Contractures can develop with great rapidity, and the only sure way of preventing them is to put every joint in the affected parts of the body through a full range of movement twice a day. Passive movements are also valuable in preventing oedema. If irritative symptoms are absent or minimal, this is a simple matter. If spontaneous pain, muscle tenderness, pain on stretching muscles or true spasm are present, then the maintenance of mobility calls for vigilance and hard work. The movements should be carried out after the limb has been heated by one of the methods already described. The physiotherapist must be content to put the joints through ranges of movement just short of those required to provoke pain, hoping to gain a wider excursion each day. Forcible manipulation is dangerous as well as painful; the muscles may be torn and even myositis ossificans has been seen as a consequence of such rough treatment. When a patient is in a cabinet respirator passive

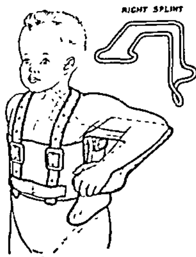


FIG. 88.—Abduction splint.
(*By courtesy of the "Lancet"*)

movements are often neglected, with the result that severe contractures develop with depressing frequency. It is usually necessary to remove the patient from the respirator not less than twice a day; on each occasion a physiotherapist or nurse should be responsible solely for moving the paralysed parts as thoroughly as possible.

(4) Formerly, splints were extensively used to prevent deformity; if a limb was held in the correct position it could not become deformed. But often the price paid for [illegible] of such [illegible] splinting [illegible] miss no opportunity of rolling or wriggling into a vicious position. It is arguable that this movement is either harmless or actually beneficial because the child is mobilizing the paralysed part. But where, as is often the case, there is a loss of muscle balance, the paralysed limb inevitably assumes a position in which the affected muscles are overstretched by the action of their more powerful antagonists. This, as will be shown presently, is prejudicial to recovery.



FIG 89—Splint for thenar paralysis used at Pinderfields Hospital, Wakefield

Splints are not often needed for adults or for children over the age of eight. The upper limbs should be supported in abduction on pillows to discourage the development of contracture of the adductors of the shoulder. The lower limbs should be placed in very slight abduction, with the knees resting on flat pillows and the feet supported at a right angle by a footboard. Each day the patient with involvement

of the lower limbs or trunk, or both, should spend about two hours lying face down. The most important reason for this is to prevent the very common *flexion-abduction* contracture of the hips; at the same time his respiratory function is improved and the patient enjoys the change of posture for its own sake. However, if only an upper limb is paralysed, a light abduction splint is convenient because the patient is then free to move the rest of his body. For the same reason, a patient with paralysis limited to one lower limb will welcome a splint, and in both cases nursing is greatly simplified. The types of splint usually needed are the following.

Upper limb

(*a*) A simple abduction frame on which the arm may rest without being bandaged to it (Fig. 88).

(*b*) A light plaster-of-Paris or plastic cock-up splint for paralysis of the extensors of the wrist.

(*c*) A splint is required in all cases of thenar paralysis, and the one used at Pinderfields Hospital, Wakefield, is most satisfactory (Fig. 89).

Lower limb

(*a*) A long splint where the whole of the limb is affected (Fig. 90).

(*b*) A short one where the paralysis is limited to muscles below the knee (Fig. 91).

(*c*) If both lower limbs are involved the two splints may be joined by a crossbar, and if the paralysis on one side is limited to muscles below the knee two long splints will still be needed.

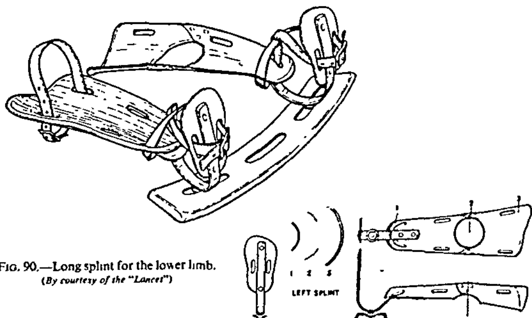


FIG. 90.—Long splint for the lower limb.
(*By courtesy of the "Lancet"*)

Plaster-of-Paris splints are easy to make but they lack durability and are easily soiled. During the Malta epidemic of 1942–43, the writer devised light duralumin splints that were simple to construct and easy to keep clean. Two years later, a large number were sent by air from Malta to Mauritius and used without modification in the treatment of the victims of the great epidemic that occurred there in 1945. The details of methods of measurement and of construction will be found in the paper by Seddon, Hawes and Raffray (1945). In both of these epidemics most of the patients were small children, and therefore the need for splints was greater than might be anticipated in the event of another large outbreak of poliomyelitis in Great Britain.

Splints are a nuisance for patients under treatment in a cabinet type of respirator, and the only ones admissible are those required for wrist-drop and for thenar paralysis.

However, they may be used sometimes with advantage for patients with respiratory paralysis who are being treated in a cuirasse respirator.

Massage is rarely necessary; its only known value is in the reduction of swelling where oedema of a limb has been allowed to occur.

Treatment designed to aid the return of voluntary power

Twenty to forty years ago the spontaneity of recovery was regarded as all-important. Bankart (1913), for example, considered that absolute rest was the best treatment. Paralysed limbs were immobilized in plaster, not merely to prevent deformity, but to reduce the flow of sensory stimuli that might reflexly provoke activity in the damaged anterior horn cells. However, the value of this treatment was never clearly demonstrated and it has been discarded.

At the other extreme was a more recent movement, originating in the United States, which was based on the reasonable hypothesis that the pattern of paralysis was determined within a matter of days. Active exercise, pushed even to the point of complete fatigue, was started as early as possible with a view to making the most of the neurones that had been spared. Yet it was not clear why intense activity was likely to be beneficial, and there are indeed a number of reasons against it which may briefly be stated.

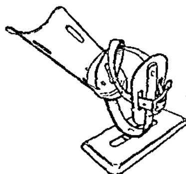


Fig. 91.—Splint for paralysis of the muscles of the leg
(By courtesy of the "Lancet")

(1) Although, as Bodian has shown, the morphological integrity of partially damaged neurones may be restored by the thirty-fifth day, it does not follow from this that these neurones are immediately capable of intense or even moderate activity.

(2) The cerebrospinal fluid sometimes continues to be abnormal, the protein content remaining high, for as long as eight weeks after the onset of paralysis. Admittedly, evidence of recovery is often apparent well within this period. But the persistence of these changes is an indication that the inflammatory process that follows the damage produced by the virus may persist for many weeks; to force activity on those neurones whose survival is still uncertain might conceivably be harmful.

(3) In sharp contrast with what is found after [illegible]

This is a sure indication that the neurones of these muscles are neither yet completely destroyed nor fully recovered.

(4) Although it may be possible to place other interpretations on the three pieces of evidence that have been advanced against early intense activity, there is no room for argument about the last, namely, the observed behaviour of muscles that are forced into activity at an early stage. Many observers, including the writer, have made frequent assessments of power of affected muscles subjected to early and intense activity and clear evidence of deterioration has been recorded, though it is not invariable.

Thus it is that most experienced clinicians pursue a middle-of-the-road policy, one of gentle activity at first, gradually increasing as the muscles regain their power. It is uncertain to what extent this mild regimen actually promotes recovery, but it does at least teach the patient how to make a proper use of muscles he had forgotten how to control. Moreover, it is the best safeguard against the persistence of a purely functional paralysis, which is peculiarly liable to afflict victims of the disease who have more than a layman's knowledge of it. Disabling functional paralysis following poliomyelitis has recently been seen in nurses who were stricken while working in infectious diseases hospitals.

Rôle of splints in recovery

Before considering the details of treatment we must examine the rôle of splints in promoting recovery from paralysis. In Britain it has long been believed that paralysed or weak muscle recovers best if it is maintained in a position of relaxation. Paralysis of the deltoid, for example, calls for the application of a shoulder abduction splint. There is no evidence whatever that relaxation is of the slightest use (Sharrard, 1954). The prevention of over-stretching is an entirely different matter. Over-stretching of a paralysed muscle facilitates the development of a contracture in its active opponent; it does more, it hinders or even completely prevents recovery.

For example, after paralysis of the thenar muscles, the thumb may have been allowed to fall into the plane of the palm; the adductors shorten and even passive abduction becomes impossible. Open correction of this contracture may be necessary, and it has frequently been observed that after this operation, and fixation of the thumb in palmar abduction, power in the previously over-stretched thenar muscles has been rapidly regained. Thus the maintenance of the *neutral* position of a joint and of the muscles that control it is essential. For the shoulder and deltoid the correct position is with the arm by the side.



FIG 92—Suspension apparatus for remedial exercises. The overhead frame and the slings were home made, the springs were made in a mechanic's shop (Malta epidemic, 1943).

Exercises

Exercises are of two kinds, *specific* and *general* or *functional*.

Specific exercises.—When a particular muscle or muscle group has been paralysed or gravely weakened, the exercise should be designed to encourage its activity: otherwise there is a risk of the patient using only the antagonists or muscles which are to some extent capable of taking over the function of *those* affected. At first the load on ... the weight of the limb being supported by springs

... ver returns the load is increased;

... of an intelligent physiotherapist.

... h week to the fourth or fifth month.

This type of exercise is predominantly ...

General exercises.—At about the fourth month, exercises of a more general kind are added, those designed to encourage use of the part as a whole. The most important of these is walking, and it is best if the first steps are taken in deep water. Indeed, the only occasion when a therapeutic pool is almost indispensable is when a patient finds it difficult to make the transition from the recumbent to the upright position (Fig. 93). During this period trick movements are not to be discouraged and supplementary movements, those brought about by muscles capable of taking over part of the action of those severely affected, are also valuable.





FIG. 93.—Patient learning to walk in water. The gutter splints for control of the knees are made from any waterproof material (plastics are particularly suitable) and the bands round the feet prevent foot-drop. (*Reproduced by permission of Miss L. Prior*)

Supportive apparatus

At about the third month the need for supportive apparatus should be considered. First, the patient may require an appliance to protect muscles that are recovering but still weak, for example, a belt for weakness of the abdominal muscles, or a leg

appliance to protect a useful but still feeble quadriceps. Secondly, he may need a[illegible] appliance to compensate for a paralysis too extensive to be amenable to reconstructiv[illegible] surgical treatment, for example, complete paralysis of both lower limbs. Thirdly, if th[illegible] patient is young, and has a paralysis that could be benefited later by operation, it i[illegible] advisable to supply an appliance until the child is old enough for operation. Arthro-desis of the tarsal joints, for instance, is a valuable stablizing operation, but it is bes[illegible] postponed until the age of twelve or later; notwithstanding the confidence of surgeon[illegible] *who perform the operation early, it cannot fail to arrest bone growth at the join[illegible]* surfaces that have been resected. Lastly, a child who can walk well without apparatus may need an appliance solely to prevent deformity being produced by the weight of th[illegible] body. Isolated paralysis of the quadriceps is not incompatible with a good gait: bu[illegible] a child (though not an adult) will run a serious risk of developing deformity at the knee

Walking

For most patients the clamant question is whether walking will be possible and [illegible]

[illegible]

limbs, or if the paralysis of a lower limb is such that adequate protection could b[illegible] given by an appliance; paralysis limited to muscles below the knee should always be dealt with in this way.



FIG 94—Parallel bars (*Reproduced by permission of Miss L. Prior*)

(2) Complete paralysis of the trunk and lower limbs, with involvement of the upper li[illegible] [illegible] the patient from using crutches, completely precludes walking an[illegible]

[illegible]

strong, walking may be just possible if the patient [illegible]

leg appliances and uses crutches. But the effort required will always be great and he may be happier in a wheel-chair.

(4) Where the paralysis is limited to the lower limbs, walking with leg appliances and crutches, or even sticks, will certainly be possible. The first steps should be taken by the third month. It is in these last two groups of cases that a pool is particularly useful. Next come parallel bars (Fig. 94), then walking with crutches and, later, sticks.

Reconstructive surgery

Preventive tendon transplantation.—The techniques of reconstructive surgery in poliomyelitis are so well described in the standard works that there is no need to refer to them here, but a recent development in the surgery of poliomyelitis must be mentioned, one that has come to be called *preventive tendon transplantation.* Loss of balance between the pull of opposing muscle groups is the most potent and continuing cause of deformity and one that cannot be controlled by external appliances, however well-fitted and maintained. There is far less tendency to deformity in a completely paralysed part; hence, where there is asymmetrical paralysis, the deforming force could be reduced or even completely abolished by suppression of the function of such muscles as are acting. This is a destructive procedure and it is far more satisfactory to transplant the tendons of acting muscles to a situation where their function will be at least harmless and perhaps even beneficial. Tendon transplantation is an old operation; this application of it, that is, as a means of preventing deformity, is recent and still in the process of being worked out. In Table I are summarized the types of tendon transplantation most commonly used at the Royal National Orthopaedic Hospital. At first the practice was to perform these tendon transplantations only when deformity due to loss of muscle balance was becoming apparent. It was then necessary to begin by correcting the deformity by manipulation and fixation in plaster. But the paralyses listed in the table so constantly give rise to particular deformities that it is preferable to carry out the tendon transplantation before

TABLE I

TENDON TRANSPLANTATION IN THE PREVENTION OF DEFORMITY IN THE LOWER LIMB

Isolated Muscles Paralysed			Isolated Muscles Acting		
Muscles	*Deformity*	*Transplant*	*Muscles*	*Deformity*	*Transplant*
Tibialis anterior	None or mild equino-valgus	None or peroneus brevis to dorsum of foot	Tibialis anterior	Calcaneo-varus	Tibialis anterior to calf
Tibialis anterior, Tibialis posterior	Severe equino-valgus	Peronei to dorsum	Peronei	Calcaneo-valgus	Peronei to calf
Tibialis anterior, Extensor digitorum, Peronei	Severe equino-varus	Tibialis posterior to dorsum	Calf	Equinus	Apparatus
Peronei	Varus	Tibialis anterior laterally	Long flexors of toes	Calcaneo-cavo varus	Long flexors to calf
Intrinsic muscles of foot	Claw toes	Long flexors of toes to long extensors			
Calf	Calcaneo-cavus	Peronei, tibialis posterior and long flexors to calf, or peronei alone to calf			

Children

Provision for the care of seriously afflicted children is easier than for adults because there is usually a home to which the child may return and in many parts of the country special schools for the physically handicapped.

As soon as it becomes apparent that a child is going to be permanently disabled, the parents should be made aware of their added responsibilities which are usually accepted readily although with a heavy heart. Even if a child is only moderately disabled some parents suggest that he should go to a special school; but if there is the slightest chance of the child being accepted at an ordinary school it should be taken. Most children afflicted with poliomyelitis are of normal or unusually high intelligence. Sooner or later they will have to face the world as it is and for this the ordinary school is the best preparation. Indeed, the physical handicap often spurs on the youngster to greater intellectual endeavours and many fairly severely paralysed boys and girls have excelled scholastically. However, special provision is required for the child with, say, complete paralysis of both legs and most education authorities provide transport from the home to the special school. There are also a few boarding schools for the gravely handicapped.

Welfare organizations

Great ingenuity has been expended in devising domestic aids for paralytics and an excellent guide entitled *Gadgets* has recently been published by the National Association for the Paralysed, Tavistock House (South), Tavistock Square, London W.C.1.

The general welfare of the victims of poliomyelitis is the special concern of the Infantile Paralysis Fellowship, an organization that is doing increasingly valuable work.

See also British Surgical Practice Poliomyelitis, Vol 7, page 94, S. Key 274.)

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ANTIBIOTICS

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INTRODUCTION

For the treatment of bacterial infections the surgeon may now choose from no less than nine antibiotics; penicillin, streptomycin, aureomycin, terramycin, [illegible]

value has been vitiated by bacterial resistance. In this article it is proposed to discuss the later antibiotics, to review the development of bacterial resistance, and to note the circumstances in which two antibiotics may be used in combination.

Aureomycin (chlortetracycline) and terramycin (oxytetracycline)

These two antibiotics, produced by *Streptomyces aureofaciens* and *Str. rimosus* respectively, are closely related chemically, and share many features in common. Both are broad spectrum antibiotics with a very similar range, inhibiting Gram-positive and Gram-negative bacteria, some rickettsiae and some of the larger viruses. Fungi are unaffected This wide spectrum of activity renders them most valuable chemotherapeutic agents, although their usefulness is impaired by the unfortunate property, possessed by all bacteria, of being able to acquire resistance. Resistance to aureomycin almost invariably implies resistance to terramycin, and *vice versa*, and resistant strains, which retain this characteristic permanently, are now common.

Administration

Both drugs are normally given by mouth and in Table I will be seen dosage schemes, and the levels which may be expected in blood and urine. It is worth noting that an increase in the dose above the maximum suggested is unlikely to result in a significant increase in the rate of absorption (Brainerd, Bruyn, Meiklejohn and O'Gara, 1951).

Following absorption aureomycin and terramycin diffuse freely through the body, and small amounts enter the normal cerebrospinal fluid. Judging by therapeutic results, in the presence of inflammation, the blood-brain barrier is passed more readily. Intramuscular injection is unsatisfactory, and for those who cannot take these drugs by mouth intravenous preparations are available. Thrombophlebitis frequently follows their use.

Toxicity

Both drugs alter the colour, consistency and odour of the stools, and both may cause abdominal discomfort and nausea. When very large doses have been given damage to the liver has been seen, and in view of this it has been suggested that the daily intravenous dose should never exceed two grammes, and that only one gramme should be given if the drug is also being taken by mouth. No other serious toxic effects are likely although prolonged administration may result in the replacement of antibiotic-sensitive bacteria by resistant organisms in the bowel or elsewhere in the body.

Indications

In surgical practice aureomycin and terramycin have been most useful in the treatment of infections due to penicillin-resistant strains of *Staphylococcus pyogenes*. These infections, discussed at greater length in a subsequent section, are now all too common, and account for more than half of the staphylococcal infections acquired by hospital in-patients. Until recently their empirical treatment with aureomycin or terramycin, without the guidance of *in vitro* sensitivity tests, has usually been successful, but with the steady increase in strains resistant to both these drugs this fortunate outcome is no longer certain. It is now advisable to prescribe treatment in the light of sensitivity tests, if possible in every case, and certainly in those which do not respond to treatment within 48 hours.

TABLE I

TABLE OF DOSAGE

Drug	*Penicillin*	*Streptomycin*	*Aureomycin*	*Terramycin*	*Chloramphenicol*	*Erythromycin*	*Polymyxin B or E.*
Loading dose if advisable	—	—	1–2g	1–2g	2–3g	—?	—
Maintenance dose	0 25–0 5 Mega 8–12 hourly or 3–600,00 units procaine penicillin. Varies greatly with type of infection	(1) Tuberculosis infection 1g 8–12 hourly for 3 days or 20–30mg./lb	0 5g. 8–12 hourly or 20–30mg / kilo. daily or I V 0 5g 12-hourly	0 5g 6–12 hourly or 20–40mg / kilo. daily or I.V. 0 5g 12-hourly	0 5g. 6–8 hourly or 30–50mg / kilo.	0·3–0 5g 6 hourly or 30–50mg / kilo.	1 5–2 2 mg /kilo. daily
Peak of blood level	Varies with dose	30–50 μg/ml.	1–3 μg/ml.	2–4 μg/ml.	16–32 μg/ml	1–8 μg/ml.	75 μg/ml.
Urine level	High: varies with dose	Up to 1,000 μg/ml	Up to 200 μg/ml	Up to 400 μg/ml.	150 μg/ml. some 90% inactive.		Low, but is effective.
Intrathecal injection	Up to 20,000 units b.d	Up to 100 mg. daily	—	—	—	—	4 mg. daily

(*From Recent Advances in Chemotherapy—Vol. III, Antibiotics By courtesy of Messrs Churchill, London.*)

Aureomycin and terramycin have been widely used for a number of other purposes, including the pre-operative suppression of bowel organisms, and the treatment of peritonitis, urinary infections, infections of the lung and some specific diseases.

Pre-operative suppression of bowel organisms and associated enteritis

The insoluble sulphonamides and streptomycin by mouth are still proving satisfactory for the preparation of patients for abdominal surgery (Morgan, 1952). When it is desired to remove as many bacteria as possible other drugs may be more effective. At the Mayo Clinic, for instance, Dearing and Heilman (1953) compared aureomycin with chloramphenicol, dihydrostreptomycin, sulphasuxidine and sulphathalidine, and concluded that aureomycin was the most effective in ridding the bowel of organisms. They recommended that it should be given in 750 milligram doses four times a day for 3–3½ days. In the next year terramycin was found to be as effective as aureomycin (Dearing and Needham, 1951), and in 1952 Dearing, Mann and Needham stated that in 2,000 patients prepared for abdominal surgery with aureomycin or terramycin, no

abnormal bleeding had been noticed, and denied that this type of preparation significantly altered the prothrombin time.

When the normal inhabitants of the bowel or some other region are removed by an antibiotic, their place may be taken by resistant organisms. These organisms may not, in normal circumstances, be able to gain a footing, and if they are potentially [illegible]

preparation of patients—unless accompanied by cultural studies of the stools—as they have met cases, some fatal, of enteritis due to resistant strains of *Staph. pyogenes*. They describe 44 patients who developed some features of this condition, usually following terramycin, but in a few cases after aureomycin, or another antibiotic, or even after no antibiotic at all. Of the patients with serious clinical manifestations, [illegible]

autopsy of a pure growth of streptomycin-resistant staphylococci from an infant treated with oral streptomycin, and it has been seen following the use of terramycin for the treatment of pneumonia and urinary infections (Jackson and his colleagues, 1951; Womack and his colleagues, 1952). Considering the extensive scale on which the broad spectrum antibiotics have been used, and the fact that antibiotic-resistant strains are becoming increasingly common, it is surprising that this condition has only been reported from a few centres It may be that it does not follow colonization of the bowel by every strain of *Staph. pyogenes*, and that this is another example of hospital [illegible]

of patients who are about to be submitted to abdominal surgery carries with it the risk of producing resistant organisms, which, if they are responsible for post-operative infections, may be unaffected by treatment. It was partially with this in mind that Jawetz and Bierman (1952) made use of mixtures of polymyxin with either neomycin or bacitracin by mouth. In the dosage used (polymyxin 400–600 milligrams daily; neomycin 1,000 milligrams daily; bacitracin 120,000 units daily) these drugs were poorly if at all absorbed, and in the absence of detectable blood concentrations were considered safe and practicable for pre-operative medication. With the possible exception of polymyxin for the treatment of infections due to *Pseudomonas pyocyanea*, there would be little likelihood of using any of these antibiotics for the treatment of established infection, and the development of resistant strains would therefore be immaterial.

Sterilization of the bowel.—So far no antibiotic or antibiotic combination has been described which will sterilize the bowel, and, indeed, it is doubtful if such a result would be altogether to the patient's advantage. Experience should decide if the good results which follow the antibiotic preparation of patients for intestinal surgery are due to a reduction in the total number of bacteria, or to the elimination of certain pathogens, and how much is due to alteration of the physical composition of the faeces.

Therapeutic value

Peritonitis.—There have been so many advances in surgery that to give credit to any single one for better results would be unjust, and it is clear that the lower mortality now seen in patients with peritonitis is due to a combination of factors. At the same time, to quote Wright and his colleagues (1951), "the invasion and subsequent uncontrolled growth of bacteria within the peritoneal cavity produce a chain reaction of

paralytic ileus, toxaemia, electrolytic imbalance and circulatory disturbances . . . when all other phases of the total bodily response to the abdominal catastrophe are therapeutically managed, the bacterial problem is the key to the lowered mortality". These authors treated 235 consecutive patients having peritonitis, 22 of whom died. They felt that aureomycin was the antibiotic of choice, and recommended that a dosage of 500 milligrams should be given intravenously twice daily until oral administration was possible. Others have commented favourably on the value of aureomycin (Rutenburg and his colleagues, 1952), and more recently terramycin has been found to be as effective (Reiss and his colleagues, 1952).

Despite the difficulties of assessment it is clear that almost without exception those who have written on this subject have credited antibiotics, and the broad spectrum antibiotics in particular, with a share in the improved results now seen in the treatment of peritonitis.

Urinary infections.—Both aureomycin and terramycin are excreted in the urine, and after comparable doses much higher concentrations are met there than in the blood. With their wide range of antibacterial activity both antibiotics are admirable urinary antiseptics, and—with the probable exception of *Proteus* and *Ps. pyocyanea*—will prevent the growth of sensitive strains of bacteria responsible for urinary infections. Despite this, the results of chemotherapy of these infections with aureomycin or any other antibiotic are not so good as might be expected. It has been recognized for a long time that infections associated with abnormalities of the renal tract, and with diabetes, are prone to relapse, and this has been common experience with antibiotic treatment. The immediate results may be good, but observation one month or more after treatment frequently shows infection with the same or another organism.

Post-operative chest infections.—As all the bacteria responsible for this condition

more toxic. They are best prescribed with the guidance of bacteriological examinations of the sputum.

Specific diseases.—Within recent years a number of specific infections have been found to respond to aureomycin and terramycin, and they now constitute a satisfactory but expensive alternative form of treatment to penicillin. These infections include syphilis, gonorrhoea, actinomycosis, anthrax and probably erysipeloid (Robinson, 1951; Rodriquez, Weinstein and Parkhurst, 1952; Chen, Dienst and Greenblatt, 1950; Wright and his colleagues, 1951; Garrod, 1952a and 1952b; and Waage, 1950).

Chloramphenicol

Chloramphenicol, produced by *Str. venezuela*, is another broad spectrum antibiotic, and is the first to be synthesized on a commercial scale. Chloromycetin, the original name of this drug is the one registered by the manufacturers. In its activity it resembles aureomycin and terramycin in inhibiting Gram-positive and Gram-negative bacteria, as well as some of the rickettsiae and viruses: the most striking difference is that it is an effective agent for the treatment of typhoid fever. Several antibiotics will inhibit the growth of *Salmonella typhi in vitro*, but chloramphenicol is the only one which can be relied on to cure the infection (the carrier state is not affected). Bacteria can become permanently resistant to chloramphenicol, and the proportion of resistant strains encountered is related to the freedom with which the drug has been prescribed.

Administration

Chloramphenicol is given by mouth, and a suitable dosage is suggested in Table I. After absorption it diffuses freely through the body, and is unusual in that an

appreciable amount enters the normal cerebrospinal fluid. Although weight for weight less active than aureomycin or terramycin (Table II), this is offset by the larger amounts which are absorbed, and the consequent higher blood concentrations. There is no entirely satisfactory preparation available for intramuscular injection.

Toxicity and indications

Where other antibiotics are available, the use of chloramphenicol has been restricted by the fear that aplastic anaemia might follow. Despite the fact that the first case was reported in 1950, the proportion of patients likely to develop this complication is not yet known, and equal ignorance surrounds the circumstances which are conducive (Lewis and his colleagues, 1952). The present tendency is to regard enteric fever as an imperative indication for chloramphenicol, and otherwise to confine its use to the treatment of infections known to be due to bacteria resistant to other antibiotics, or to the treatment of infections for which other suitable antibiotics are not available. It should certainly not be prescribed on trivial indications.

Polymyxins

Five polymyxins—A, B, C, D and E—have been isolated from *Bacillus polymyxa*, a fairly common soil organism. They are all bactericidal antibiotics which *in vitro* are active against many Gram-negative organisms, including *Ps. pyocyanea*, but excluding *Proteus.*

TABLE II

SENSITIVITY OF CERTAIN PATHOGENIC SPECIES

AVERAGE MINIMUM INHIBITORY CONCENTRATION IN μG/ML.

	Penicillin	*Strepto-mycin*	*Aureo-mycin*	*Terra-mycin*	*Chloram-phenicol*	*Poly-myxin*	*Baci-tracin*	*Erythro-mycin*
Staph. pyogenes	0.02R	16	0.5R	1R	16R	200+	2.5	0.3
Strep. pyogenes	0.01	50	0.5	0.5	3	400+	0.3	0.02
Strep. viridans	0.03	3–12	0.4	0.4	2–10	100+	—	0.06
Strep. pneumoniae	0·02	12	0.3	0.2	2.5	100+	—	0.02
Strep. faecalis	2.5	50	0.6	0·3	10	100+	3	2
Myco. tuberculosis	1,000+	0.5	—	12.5	—	—	—	—
Cl. tetani	0.1–10	1,000	0.1	0·5	10	1,000+	—	0.8
Cl. welchii	0.1	100–2,000	0.1	0.5	2	1,000+	—	1.6
B. anthracis	0.02	1	0.1	0.1	3.5	—	—	—
E. rhusiopathiae	0.08	12–50	2	—	7	80+	—	—
A. israeli	0.06	23	4.2	2·2	2.8	—	—	—
N. gonorrhoeae	0.003	6	0.8	0.8	0.8	300	6	0.04
N. meningitidis	0.03	5	0.5	1	1	—	—	0.3–5
Bact. coli	—	6R	5R	5R	10R	0.2	—	50+
S. typhi	10	4–32	1.5	3	3	—	—	1,000+
Shigella— various species	16–50	3–7	1.5	2	3	—	—	1,000+
H. influenzae	1	1.2	0.6–2.5	0.5	0.3	0.25–0.6	750+	1.6
H. pertussis	1	1–3	2	2	8	—	—	0.6
Proteus vulgaris	20R	50	200	200	25R	1,000+	1,000+	50+
Kleb. friedlanderi	10–4,000	0.3–8	0.4	0.8	2	—	—	12
Ps. pyocyanea	1,000	50	200	200	500	1	1,000+	100+
Brucella	20	0.5–4	3	2	3	—	—	100+

R—Resistant strains common.

(*From Recent Advances in Chemotherapy—Vol. III, Antibiotics. By courtesy of Messrs. Churchill, London.*)

Toxicity

All the polymyxins are polypeptides, and in common with other antibiotics of this nature they may cause renal damage. Other harmful effects which have been reported

to this problem is found, hospital staphylococcal infections are likely to oc their successful chemotherapy will depend on the discovery of new an Amongst out-patients the opportunities for resistant strains to spread ar great, but even here a recent report showed that 16 per cent of staphylococci from casualty patients were resistant to penicillin, as compared with 6·5 isolated three years previously (Birnstingl, Shooter and Hunt, 1952).

No other organisms have presented serious problems by the develop resistant strains, and for one—the gonococcus—this is all the more remar resistance may be produced very readily in the test tube. Despite this, apart fro early unconfirmed reports, there have been no clear examples of infection penicillin-resistant organisms. Pathogenic haemolytic streptococci of Lan group A (*Str. pyogenes*) appear to be incapable of developing resistance, fact accounts for much of the indifference with which surgical infections w organism are now regarded.

Streptomycin

Whatever may be the case with penicillin, resistance to streptomycin is related to treatment with streptomycin, and the proportion of streptomycin-r strains depends on the frequency with which streptomycin is used. All organis become resistant, and as the acquisition of resistance is dependent on the sp growth, rapidly growing bacteria may become resistant within a few hours slow-growing tubercle bacilli may need weeks. It is for this reason, and streptomycin is a toxic drug, that it has been suggested that streptomycin sho confined to the treatment of tuberculosis, and to the treatment of urinary infe In the latter, the high urinary concentrations make streptomycin an excellent antiseptic, and treatment prolonged beyond two or three days is neither ne nor desirable, as if by that time sterility has not been achieved, the infecting org will almost certainly have become resistant. Streptomycin is most active at an a pH, and failure to adjust the urine before treatment will impair or null efficiency of the drug.

In the treatment of tuberculosis the development of resistant bacteria c markedly delayed by the combination with streptomycin of another active ager as isoniazid, and this is now the accepted practice. How far this principle c applied to the treatment of other infections is unknown.

Broad spectrum antibiotics

Aureomycin, terramycin, chloramphenicol and erythromycin behave mor streptomycin than penicillin in that all bacteria may become resistant. This pro a relatively slow one, but there have been numerous reports showing a steady the proportion of resistant strains.

Staphylococcus pyogenes

As one of the principal uses of the broad spectrum antibiotics is for the trea of infections due to penicillin-resistant strains of *Staph. pyogenes*, their effe staphylococci has been closely watched. It appears that resistant strains did not before the introduction of these drugs, and that they have been produced by contact with them. Needham and Nichols (1953), quoting figures from the that they isolated no aureomycin-resistant staphylococci in 1948, b

Needham, quoted by

aureomycin-resistant staphylococci had risen to 45 per cent. Similar observations have been made in many other parts of the world. Chabbert and Terrial (1952), for instance, reported from France that 23 per cent of staphylococci isolated by them were not only resistant to aureomycin and terramycin, but to all other available antibiotics as well.

A situation of this sort has so far been met by the use of a new antibiotic, and for the moment erythromycin fills this rôle. What evidence we have suggests that its useful life may be somewhat restricted. Herrell and Nichols (1953) isolated no strains of *Staph. pyogenes* resistant to this antibiotic before its introduction, but two resistant strains developed during the treatment of the patients described in their paper, and there are indications from another centre that such strains may be produced with ease (Editorial, 1953).

Other bacteria

Increases in the proportion of resistant strains of several bacteria, and particularly of coliform bacilli, have been reported by several authors. This process is still continuing.

Cross-resistance

For practical purposes the susceptibility of an organism to penicillin is unrelated to its reaction to streptomycin, and there is little connexion between the effect of these drugs and the activity of the broad spectrum antibiotics. Among the latter cross-resistance may be seen. Organisms resistant to aureomycin are almost invariably resistant to terramycin, and a contrary finding should suggest the possibility of technical errors. Between aureomycin and chloramphenicol there is less connexion. Gram-positive bacteria behave independently, but with Gram-negative organisms resistance to one antibiotic may involve resistance to another.

Although penicillin sensitivity is unrelated to sensitivity to aureomycin, staphylococci resistant to aureomycin and terramycin nearly always are, in fact, resistant to penicillin. This is probably because the predominant staphylococcus, when the broad spectrum antibiotics were introduced, was already penicillin-resistant; the alternative possibility that penicillinase-forming staphylococci become resistant to aureomycin more readily than others has not, however, been extensively investigated.

Bacterial dependence and stimulation

It has already been stated that bacteria may become resistant to streptomycin with great rapidity; this process may be carried a stage further and bacterial strains develop which are actually dependent on streptomycin for growth. Dependence, which has also been seen with chloramphenicol, occurs both in the test tube and in patients during treatment, and it is conceivable that the course of an infection due to streptomycin-dependent bacteria might be prolonged by treatment. This has not been considered a serious risk, and much more attention has been paid to the likelihood of inadequate doses of an antibiotic stimulating bacterial growth.

It has been known for a long time that sublethal concentrations of a disinfectant may stimulate bacteria [illegible] is no real indication that a similar result will follow in the quite different circumstances met in the body, or that if it does the bacteria will necessarily be more harmful. This is supported by the rare occasions on which stimulation has been shown to occur in experimental infections, and the almost complete lack of evidence that it occurs during the treatment of patients.

Infections due to yeasts may be exceptions; these organisms have been shown to

be stimulated *in vitro* by antibiotics, and they are not uncommonly found in patients who have received long courses of treatment. The two facts are not, however, necessarily related, and it is at least as likely that yeasts thrive in these patients because the bacteria which normally prevent their growth have been abolished. For excellent and extensive reviews of dependence and stimulation the reader is referred to Garrod (1950, 1951).

COMBINED CHEMOTHERAPY

To use two antibiotics instead of one in the hope of producing better results is a very natural tendency, and is becoming an increasingly common practice. Indications for it have been discussed recently by Garrod (1953) who found three minor ones, and two of more significance. The minor ones comprised the urgent undiagnosed case, mixed and double infections, and the possibility of preventing toxic effects by using rather lower doses in combination than would be required if one toxic drug was used alone. The major indications were the prevention of acquired resistance, a possibility which has already been mentioned in connexion with streptomycin, and synergism.

Synergism and antagonism

When two antibiotics are used together the resulting action may be no better than would be expected from the use of each agent individually, or it may be additive: in some cases synergism results, that is to say, a more successful result than would have been expected from the sum of the two antibiotics given separately, and in others antagonism may occur, and the result be worse. To avoid antagonism and achieve synergism is the aim of combined treatment, but no easy method has yet been evolved of deciding how this may be achieved, and it is not even clear in which infections it may be possible.

Jawetz and his colleagues, to whom we are indebted for many of our ideas on this subject, found that when cultures of *Str. faecalis* were exposed to penicillin, not all the bacteria were killed; the addition of streptomycin, even in amounts too small to be effective alone, resulted in an increased rate of killing and eventual sterilization (Jawetz, 1952). The same authors have shown that in the laboratory, aureomycin, terramycin and chloramphenicol will interfere with the bactericidal action of penicillin, and they have drawn up a guide to the expected results of using antibiotics together. These agents they divided into Group I drugs which were bactericidal, penicillin, streptomycin, bacitracin and neomycin, and Group II drugs which were bacteriostatic, aureomycin, terramycin and chloramphenicol. The effect of using Group I drugs together was frequently synergistic, but Group II drugs were no more than additive. When Group II drugs were used with those of Group I, they sometimes interfered with the bactericidal action of the Group I drug, and antagonism was seen. This only took place when the organism concerned was sensitive to the bactericidal component of the drug mixture; if it was more resistant, though, of course, not if fully so, synergism might be observed.

These are laboratory results, and before mentioning their applicability to the treatment of patients, it should be noted that they have been obtained by observing the rate at which bacteria are killed. Similar information cannot be obtained by conventional sensitivity tests based on the power of an antibiotic to inhibit growth, and as Garrod (1953) points out, the extra labour involved in work of this sort is great.

Subacute bacterial endocarditis due to *Str. faecalis* provides the clearest example of a disease in which treatment by a synergistic combination of antibiotics is desirable, and here it is not only desirable but even necessary if the patient is to be cured. It is probable that in time other diseases will be found, in whose treatment synergism can play a part.

Antagonism, like synergism, can be demonstrated in experimental infections in animals, although the conditions need to be rigorously defined, and an excess of antibiotics will prevent the phenomenon appearing. The only undoubted report of antagon-

of penicillin and aureomycin, as opposed to 13 out of 43 patients treated with penicillin alone. It has been suggested that conditions in the meninges may be ideal for the development of antagonism, as this is an area in which an excess of antibiotic is rarely present, The failure to observe antagonism in other infections may reflect the common practice of administering much larger doses of an antibiotic than are strictly necessary.

It will be clear that much more work of great interest needs to be carried out on the combined use of antibiotics. At the moment the prescription of antibiotics together is frequently unnecessary, and unless controlled by time-consuming laboratory tests, is liable to lead to unpredictable results.

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BLOOD TRANSFUSION

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GENERAL

The development of organized blood transfusion services has made possible the transfusion of blood and blood products on a scale previously considered to be necessary only in time of war. Although there is evidence that some patients, notably those suffering severe traumatic injuries, are not being transfused with blood in sufficiently large amount (Clarke, 1952), the ready provision of this fluid carries with it the danger of its too free prescription, particularly if the decision to transfuse is left to the most junior members of a hospital's medical staff. Not only does careless prescribing jeopardize the supply of blood for patients requiring large volume transfusions, but transfusion is not without hazard and should not be administered if a simpler and safer treatment can effect a similar end result. It is probable that the mortality from blood transfusion approaches that of appendicectomy, therefore, the decision to transfuse warrants a similar careful assessment.

BLOOD GROUPS

ABO groups

Although, recently, additional blood group antigens have been discovered, incompatibility following an error in ABO grouping still carries the greatest threat to life, and occurs principally when corpuscles containing an A or B agglutinogen are transfused to a recipient whose plasma contains anti-A or *anti-B agglutinisn, for example,* a patient of group O. On the other hand, haemolytic reactions have been reported following the transfusion of group O blood (often still misleadingly termed universal donor blood) to recipients belonging to group A or AB (Mollison, 1951). The plasma of the donor blood transfused contained anti-A antibodies with *immune* characteristics which had reacted with the A antigen in the patients' corpuscles. Such donors are termed "dangerous group O donors," and may have developed their immune antibodies as the result of protective inoculations. Not only is the risk of a serious reaction minimized when the blood transfused is of homologous ABO group, but, since nearly 50 per cent of Europeans and White Americans are group A, a more economical use is made of the available blood.

Rh groups

Eleven principal Rh antigens can [illegible] and have been designated by the letters, C [illegible], was the first Rh antigen to be discovered, and the [illegible] "D-negative" are clinically synonymous with "Rh-positive" and "Rh-negative" respectively. The D antigen is also clinically the most important Rh antigen and,

providing careful direct matching by modern techniques precedes every blood transfusion, there are very few instances in which the other antigens have to be considered.

One in six patients (17 per cent) are Rh-negative and may develop immune anti-Rh agglutinins (anti-D) in their plasma if transfused with Rh-positive blood, or, if women, they bear Rh-positive children. Incompatibility within the Rh system is avoided if Rh-negative patients are transfused only with Rh-negative blood. Rh-positive blood is tolerated by an Rh-negative male or female patient who has not previously been transfused, or who has not borne an Rh-positive child, for the patient's plasma does not then contain anti-Rh. In emergency, Rh-positive blood may, therefore, be transfused to such a recipient. The Rh-negative female who has received a transfusion of Rh-positive blood may, however, subsequently give birth to children severely affected with haemolytic disease of the newborn, since the double sensitization of an Rh-positive transfusion and an Rh-positive baby readily stimulates the formation of anti-Rh Such children are often still-born. *Therefore, except to save life, and when no other transfusion fluid is available, Rh-positive blood must be transfused to a female patient who might later bear a child only if she is known to be Rh-positive.*

Other blood group systems

Seven distinct, and genetically unconnected blood group systems in addition to ABO and Rh, have now been established, these are. MNS, P, Kell, Lutheran, Lewis, Duffy and Kidd. These systems and the Rh antigens other than D assume clinical importance only when the patient's plasma contains the equivalent antibodies. Naturally-occurring antibodies exist only rarely, and immune antibodies to one or more of these systems are not so readily provoked by pregnancy or blood transfusion as are anti-D antibodies. They are particularly liable to develop, however, if the same blood group antigens enter the patient's circulation on repeated occasions. For this reason a patient should not be transfused repeatedly with blood from the same donor; and blood from her husband, or her sons or daughters, should not be transfused to a woman.

Patients who have developed immune antibodies to these blood group systems, or to Rh antigens other than "D" have been termed "dangerous recipients of transfusion" (Tovey, Warren and Wood, 1953) because: (1) The antibodies they have formed will react with certain donor bloods of their own ABO and Rh group, (2) the potential incompatibility cannot be detected by the simpler types of direct matching test, such as a slide test, and (3) they may suffer a haemolytic transfusion reaction when transfused with so-called "universal donor blood" (group O) even when it is Rh-negative unless it has been confirmed to be compatible by one of the special techniques described below. Although it is apparent that immune blood group antibodies may be present in the plasma of any patient who has previously been transfused or who has been pregnant, in practice they are most frequently found in patients who have reacted adversely to blood transfusion and women who have had stillborn or jaundiced babies. When present, the patient will tolerate only blood which is "negative" to the corresponding antigen. In some cases there may be considerable difficulty in finding compatible blood; for example, only one in a hundred persons is group O and "e-negative."

Technique of ABO and Rh grouping

Blood grouping and direct matching are among the few laboratory tests in which an error can lead directly to the death of a patient, and such tests should be made only by trained persons. A doctor who is to do these tests must receive a definite course of laboratory training and must keep himself in practice.

ABO grouping

The technique of ABO grouping is fully described in *British Surgical Practice:* Blood Transfusion Theory, Vol. 2, page 211.

Rh grouping

Only the D group of recipients need be determined. Blood donors must be classified with anti-D serum as D-positive or D-negative, and the D-negative donor further tested with anti-C, anti-E and anti-D^u sera to detect "intermediate" types of Rh. The corpuscles of an Rh-negative donor do not react with any of these sera.

Determination of D group is carried out as follows. One drop of a 5 per cent suspension of red corpuscles in sterile normal saline and one drop of a saline-reacting anti-D serum are delivered into a precipitin tube by a Pasteur pipette. A suspension of known D-positive corpuscles and one of known D-negative corpuscles are similarly added to tubes containing anti-D serum, for inclusion as a positive and a negative control. The three tubes are tapped on the bench to mix the contents, capped and left in the incubator at 37° C., for two hours. The sediment in each tube is then transferred by Pasteur pipette to a slide, and examined for agglutination under the low-power of the microscope. In a case of urgency and if the anti-D serum is potent, a result may be obtained after 15 minutes incubation. Immediately after mixing, the tubes are centrifuged for 1 minute at the rate of 3,000 revolutions per minute. The contents are re-suspended by flicking each tube with the finger, and after incubation at 37°C. for 15 minutes, the tubes are again centrifuged at the rate of 1,000 revolutions per minute before reading.

Direct matching test

Direct matching of the donor's corpuscles against the recipient's serum should be regarded as an essential preliminary to every blood transfusion to check that an error has not been made in the ABO group of the donor or recipient, and to exclude incompatibility from irregular, naturally-occurring or immune, agglutinins in the recipient's serum. In cases of urgency, plasma or a plasma substitute may be transfused until the matching tests are completed. *Only in the gravest emergency should a direct matching test be omitted.* A history sheet indicating whether the patient has previously been transfused, the response to these transfusions, and, if a woman, the outcome of each pregnancy, should accompany the sample of blood for direct matching, to enable the pathologist to determine which technique should be used.

formation), or agglutination caused by non-specific cold auto-agglutinins may be differentiated by finding a similar agglutination in the sediment from the control tube.

When the patient has had a previous blood transfusion or has been pregnant, an indirect anti-globulin (Coombs') test and an albumin tube test, both tests being carried out at 37° C., should be included in addition to the saline test at room temperature. If for any reason an indirect anti-globulin test cannot be done, the albumin test should be carried out as a titration (doubling dilutions) to seven tubes, using AB serum as diluent, since certain immune antibodies, which, undiluted, give a positive anti-globulin test, show zoning in albumin and give an apparently negative result unless titrated. The albumin test is carried out in the same manner as the saline test, using a 5 per cent suspension of corpuscles in 20 per cent bovine albumin.

The indirect anti-globulin test consists in mixing one drop of approximately 50 per cent suspension of the donor's corpuscles in saline with two to five drops of the recipient's serum. As a positive control, known D-positive corpuscles are incubated simultaneously with a very weak incomplete anti-D serum, the negative control is the patient's own corpuscles in their own serum.

After incubation for two hours at 37° C., the corpuscles are washed three times with saline and then made up as a 10 per cent suspension in saline; one volume of this suspension is mixed with an equal volume of anti-globulin reagent on a scrupulously clean opal tile. Absence of agglutination within ten minutes of mixing indicates the blood to be compatible.

Technique in a case of urgency

A saline tube test and an albumin tube test are prepared, and the tubes centrifuged at the rate of 3,000 revolutions per minute for one minute immediately after adding the cell-suspensions The tubes are flicked with the finger to re-suspend the contents. Gross incompatibility, most probably the result of an error in ABO grouping, is shown by agglutination on re-suspension. In the absence of visible agglutination, the saline tube is left to stand at room temperature, and the albumin test incubated at 37° C., for ten minutes The tubes are then centrifuged at the rate of 1,000 revolutions per minute for one minute, and examined for haemolysis and agglutination as described in the preceding section

In practised hands an urgent test, including determination of the patient's ABO and D group, can be completed within twenty to thirty minutes of the recipient's blood sample being received in the laboratory. The risk of technical error is increased in an atmosphere of haste, however, and these methods do not give the same safety to the recipient as an anti-globulin or a seven-tube titration test, which take at least two hours to complete.

Technique when facilities are limited

The following technique is permissible only when there are no facilities for more sensitive tests. It will detect gross ABO incompatibility and only some of the stronger immune antibodies.

Two drops of the donor's whole blood (citrated or oxalated) are mixed with two drops of the recipient's serum on a microscope slide. The slide is warmed and rocked over an electric lamp for three to five minutes. The donor's corpuscles become agglutinated if they are incompatible. Drying of the mixture may cause false agglutination, and the recipient's own corpuscles are tested against his serum at the same time as a control

INDICATIONS FOR TRANSFUSION

While haemorrhage and chronic anaemia remain the main indications for blood

transfusion, much work has been done in the past few years on the value of tran fusion for the treatment of haemorrhagic disorders, and in the transfusion of certai separated elements.

Platelet deficiency

Attempts to transfuse blood platelets to cases of essential thrombocytopaenia hav in the past been unsuccessful because the platelets have adhered to the surfaces of th blood taking and administering units. Platelets may now be transfused if the inne surfaces of all apparatus with which the blood comes in contact are treated wit silicones. The blood transfused must be fresh, and the most effective platelet surviva is obtained when platelet-rich blood from a polycythaemic donor is collected an transfused with multiple siliconed syringes and needles (Stefanini and Dameshek 1953). Concentrates of platelets suspended in their own plasma or saline have als been used, but are less satisfactory. Repeated transfusions may become progressivel less efficacious probably because of the development of platelet antibodies, and suc transfusions should be reserved until the need is great, for example, to ensur a relatively bloodless field during splenectomy. A simple test has recently bee described (Tullis, 1953) for the detection of platelet antibody in the serum. Platele transfusions are usually of little benefit to patients whose serum shows a significan platelet antibody titre.

Other clotting elements

Transfusion arrests haemorrhage in haemophilia providing the blood is transfused within 24 hours of collection and the recipient has not become refractory. Patients refractory to citrated blood may respond to heparinized donor blood (Van Creveld and Paulssen, 1952). Fresh blood is also necessary for cases of hypoprothrombinaemia [illegible] subsequent to liver damage, and for factor V deficiency. Factor [illegible] isease, which clinically [illegible]

Leucocytes

Transfused leucocytes are rapidly removed from the circulation by segregation in the pulmonary capillaries and appear to be of no value (Lanman, Bierman and Byron, 1950).

TRANSFUSION FLUIDS

The following fluids other than crystalloids are available for transfusion: (1) Stored citrated blood; (2) concentrated red cells, (3) fresh citrated blood; (4) plasma or serum (fluid and dried), and (5) plasma substitutes.

Stored citrated blood

Blood collected aseptically into acid-citrate-dextrose solution (2 per cent disodium citrate, 100 millilitres; 15 per cent glucose, 20 millilitres) in the proportion 420 to 430 millilitres blood to 120 millilitres anticoagulant, is satisfactory for transfusion for up to twenty-one days if stored between 4° C. and 6° C. Following transfusion the red cell survival of blood stored up to seven days equals that of fresh blood, and after fourteen days storage is inferior by only 10 per cent. Leucocytes disintegrate in a few hours, and platelets disappear in about four days. Immune bodies and complement undergo slow deterioration. The principal value of stored blood as a therapeutic agent is, therefore, to replace blood lost or to provide red blood corpuscles for patients with anaemia.

During storage, potassium passes out of the red cells into the plasma, which after fourteen days storage contains 30–40 milligrams of potassium per 100 millilitres (Melrose and Wilson, 1953). Following most transfusions, dilution by the recipient's plasma is effective in preventing the concentration of potassium reaching toxic levels, but the possibility of causing dangerous hyperkalaemia has to be considered when large volumes of blood are transfused rapidly by the intra-arterial route to an exsanguinated patient. The blood transfused should then preferably be not more than seven days old.

Citrated blood cannot be sterilized and is a suitable medium for bacterial multiplication. Chance bacteria introduced at the time of blood collection are prevented from multiplying by constant storage at 4° C.–6° C. and by the bacteriostatic effect common to most samples of fresh blood; in fact, the blood of many donors is actively bactericidal. These bactericidal properties are rapidly lost and the bacteriostatic activity gradually weakens during storage. During storage, blood for transfusion must consequently never be allowed to warm above 6° C. even for short periods of time, and bottles must remain sealed until the time of transfusion. If sampling is necessary because of direct matching tests, or in the preparation of red cell concentrates, the blood must not be stored for more than a further 24 hours before it is transfused because of the danger of rapid multiplication of bacteria introduced accidentally at the time of sampling.

Concentrated red cells

These are prepared by removing the supernatant plasma from bottles in which the red corpuscles have sedimented during storage, or which have been centrifugalized, and are the logical transfusion fluid for patients with anaemia Direct matching tests must be performed between the recipient's serum and the cells of the individual bottles of blood, before the cells are pooled. The blood used must not have been stored for more than seven days, and the concentrate must be transfused within 24 hours of preparation Red cells "washed" in normal saline may be transfused if there is evidence that the patient reacts adversely to human plasma

Fresh citrated blood

Freshly collected blood is essential for transfusion in certain haemorrhagic states, and it is possible that its content of complement and immune bodies may be of value in infective conditions. Blood for immediate use may be collected into 3 per cent trisodium citrate solution, in the proportion of 440 millilitres of blood to 100 millilitres of sodium citrate solution. The blood should be negative to a Khan or Wassermann Reaction before it is transfused

Plasma and serum (liquid and dried)

Plasma is prepared from citrated blood It contains fibrinogen and the total protein content is about 4 5–5 per cent Serum, prepared from clotted blood, contains no fibrinogen but about 7 per cent of protein. Liquid plasma or serum should be stored in a cool, dry, dark place. Refrigeration is not necessary. It should not be used unless crystal clear, cloudiness or deposits may be caused by bacterial contamination.

Dried plasma and serum are more stable and are stored in a similar manner to the liquid products. Each bottle is issued with a bottle containing non-pyrogenic sterile distilled water, in an amount equivalent to the original volume. If, after adding water, complete solution is delayed beyond 5–10 minutes, the bottle should not be used. Two or four times concentrated solutions may be prepared by adding fluid equivalent to [illegible]

us[illegible]

cies, before whole blood is available or before direct matching tests have been completed. They contain no group antigens and may be given without regard to the group of the recipient. These fluids are used mainly in the treatment of burns, and also of crush injuries, and acute protein loss into the alimentary tract.

Plasma substitutes

Plasma substitutes are solutions of macromolecular substances which possess properties (such as viscosity and colloid osmotic pressure) closely resembling those of plasma, and are not toxic or antigenic. They do not contain haemoglobin, protein (except in gelatin solutions), antibodies, or clotting factors and have only slight buffering effects. They may be given to recipients belonging to any blood group. They should be stored in a cool, dry, dark place; refrigeration is not necessary.

The solutions at present used as substitutes contain mixtures of molecules of varying size. The retention of these solutions within the vascular system, and therefore their efficiency in restoring blood volume, depends upon the proportion of large and small molecules contained in the solution. In Great Britain the tendency has been to prefer a molecular composition such that not more than 25 per cent of the dose injected is excreted in the urine in 24 hours.

The commoner plasma substitutes are solutions of dextran, polyvinylpyrrolidone or gelatin (U.S.A. only).

Dextran is a polysaccharide which is synthesized from sucrose by an exocellular enzyme produced by *L. mesenterioides*. It has been extensively used in Europe (Bull and his colleagues, 1949; Thorsen, 1949) where it was first introduced in Sweden, and in U.S.A. It is slowly metabolized in the body (Pulaski, 1952) and presumably excreted completely.

Polyvinylpyrrolidone is a synthetic substance polymerized from acetylene and formaldehyde which has been used mainly on the Continent of Europe and to a lesser extent in England (Arden, Mandow and Stoneham, 1951) and other countries. Its fate in the body is not known. Ravin, Seligman and Fine (1952) state that large molecules may be retained in the tissues for a long time, possibly for years. Consequently, solutions of polyvinylpyrrolidone for clinical use are prepared with small molecular polyvinylpyrrolidone, rapidly excreted by the kidneys; the blood volume restoring effect of the solution is therefore comparatively short-lived.

Solutions of [illegible] from hides or bones have been used almost exclusively in the United S[illegible] The commercially available solut[illegible] room temperature, and have therefore to be warmed before use. Recently "modified gelatin" has been prepared, solutions of which remain fluid at temperatures as low as 4° C. (Pulaski, 1952). The use of gelatin is still largely experimental.

Plasma substitutes are not complete substitutes for plasma and should therefore be used with discretion. Their main use is the restoration of a depleted blood volume when supplies of blood or plasma are lacking or are inadequate. They should never be used for the treatment of anaemia or hypoproteinaemia. In places where transfusion services are poorly developed or are lacking, in national emergencies, and during the temporary absence of blood or plasma, plasma substitutes have an important part to play. The ideal plasma substitute has yet to be made

Plasma substitutes may be used for the treatment of oligaemic shock caused by haemorrhage or injury, when it is expected that a satisfactory response will follow the injection of 1,000 to 1,500 millilitres; when larger transfusions are needed blood (or plasma) should be given as well.

[illegible] should not normally be given in such quantities that the haemo- [illegible] w 10 4 grammes per cent (70 per cent Haldane) [illegible] ever, the immediate object of resuscitation is the

restoration to normal of a depleted blood volume, and, in the absence of blood or plasma, it may be necessary to transfuse a volume of plasma substitute which will lower the haemoglobin concentration below 10·4 grammes per cent. Operation may often be successfully performed when the blood volume has been restored although anaemia has been caused by excessive transfusion of plasma substitute. Such anaemia may be corrected post-operatively by blood transfusion, remembering that the circulation is abnormal in the presence of post-haemorrhagic anaemia.

Patients with burns or crushing injuries may be treated successfully by the transfusion of plasma substitutes. Bull (1952) has reported that when large transfusions are needed plasma should, if possible, be used after a quantity of plasma substitute equivalent to the calculated normal plasma volume of the patient has been given; if plasma is not available the transfusion may be continued with plasma substitute.

Plasma substitutes may interfere with cross-matching tests; a specimen of blood for this test should always be collected before giving a plasma substitute. Febrile and urticarial reactions have been reported after the use of dextran (Maycock, 1952); their incidence did not exceed those observed following blood transfusion.

Plasma fractions

The constituent proteins of human plasma can be separated by appropriate techniques into a number of fractions, that is the proteins associated with blood clotting, the albumins, the *gamma* globulins and the *alpha* and *beta* globulins (Cohn and his colleagues, 1944; Kekwick, Mackay and Record, 1946, Kekwick and Mackay, 1953). Some of these fractions have proved useful in certain fields of surgery.

Fibrinogen and thrombin

Fibrinogen in the presence of thrombin becomes insoluble and forms the fibrin clot. Fibrinogen and thrombin, prepared in concentrated form may be used as such, or in the form of fibrin foam. Fibrinogen and thrombin are prepared as dry powders The former is reconstituted by the addition of sterile distilled water, the latter by the addition of sterile 0 9 per cent saline. By adjusting, in the light of experience, the proportion of thrombin to fibrinogen, the clotting time of the mixture can be controlled to suit the particular manipulation for which it is being used.

The chief use of fibrinogen and thrombin is in skin and nerve grafting where the clotted fibrinogen is used as an adhesive agent to hold the graft in place. Skin grafts are more rapidly vascularized using this method, and pigmentation is said to be less in the healed graft Fibrinogen, given intravenously as a 2 per cent solution, has been used to diminish the clotting time in haemophilia The fibrinogen fraction prepared from normal blood apparently contains, as a contaminant, a globulin which is deficient or lacking in the blood of haemophiliacs. Its nature is not known. The amount of this globulin varies from preparation to preparation of fibrinogen, so that all preparations are not equally effective.

Fibrinogen has also been used successfully to treat the condition of incoagulability of the blood associated with severe abruptio placentae, long standing intra-uterine foetal death, and the syndrome of amniotic fluid embolism. In all these conditions incoagulability is accompanied by hypofibrinogenaemia or afibrinogenaemia. (Reid and colleagues, 1953a, 1953b, Weiner, Reid and Roby, 1953)

Fibrin foam is a dry sponge of clotted fibrinogen (Bering, 1944) used in conjunction with thrombin solution for haemostasis, particularly in brain and chest operations and to a lesser extent in abdominal and dental operations. The foam itself is devoid of haemostatic action, but, soaked in thrombin solution it provides a large surface relative to its bulk, where the blood comes into contact with the thrombin which is the active clotting agent, and a scaffold for the resulting clot. Fibrin foam is rapidly and completely absorbed and causes no reaction in the surrounding tissue. It is useful for

preventing adhesion of the brain to overlying dura, but it cannot be used for repairing dural defects.

In the United States of America homologous serum jaundice has been attributed to the use of certain batches of fibrinogen and thrombin.

Albumin solution

Purified human albumin, as a hyperoncotic (25 per cent w/v) solution has been used mainly in U.S.A., for restoring a depleted blood volume in "oligaemic shock" and as a means of introducing large amounts of protein in a small fluid bulk into the circulation in diseases associated with a low plasma albumin concentration.

Albumin solution has certain practical advantages. One hundred millilitres of a 25 per cent solution contains approximately the same amount of protein as 500 millilitres of normal citrated plasma. If heated at 60° C., for 10 hours, the solution appears no longer to carry the risk of transmitting homologous serum jaundice (Paine and Janeway, 1952). On the other hand it is expensive to prepare, and if given in single massive transfusions may cause circulatory overloading. A rate of 15 grammes per hour, is tolerated in most instances up to a total load of 1 gramme per kilogram body weight in a single transfusion (Kekwick and Mackay, 1953).

Comparatively small volumes of albumin solution will restore a depleted blood volume because the solution is hyperoncotic and attracts fluid into the circulation from the extravascular space (Stead and Ebert, 1942); each gramme of albumin transfused is said to increase the plasma volume in this way by 13 0 to 14 0 millilitres (Scatchard, Batchelder and Brown, 1944). If the extravascular body water is deficient, the expected increase in blood volume will not occur. It is therefore essential to correct any dehydration, which may be present, and to maintain a state of normal hydration when albumin is used to treat patients with oligaemic shock.

The use of albumin solution to control the fluid retention of hepatic cirrhosis (Faloon and colleagues, 1949a, 1949b; Post, Rose and Shore, 1951) and nephrosis (Leutscher, Hall and Kremer, 1949) has met with variable success. The transfusion of albumin to these patients is probably of greater value as a form of intravenous protein alimentation.

ORGANIZATION OF A HOSPITAL BLOOD BANK

A hospital blood bank must be supervized by a senior member of the medical staff of the pathological department, who should be responsible not only for the technical processes necessary for the safe storage and grouping of blood but also for ensuring an adequate supply and the avoidance of waste

Accidents can be avoided only if trained and experienced staff are employed at every stage from the preparation of the blood collecting apparatus to the issue of the grouped and matched blood for transfusion. It is essential that a definite order of procedure for all techniques be evolved and rigidly followed, and the routine com- [illegible] anti-sera for emergency [illegible] me place. Anti-sera for use should, (1) be labelled, (2) be [illegible] (3) have been subjected to frequent control tests.

[illegible] hospital should keep a record book showing the date and details of each [illegible] (ABO and Rh); details [illegible] a or serum [illegible] g the trans- transfused; the nature of any reactions, and [illegible] fusion. The careful recording of serial numbers may provide the only means of tracing and checking a donor's blood if there is any question of incompatible transfusion, or homologous serum jaundice. Regular instruction should be given to members of the

medical and nursing staff in the need for care in the handling of blood and blood products. A recent survey indicates that more than a third of the avoidable accidents of transfusion are the result of transfusing blood intended for another patient, or similar acts of carelessness (Tovey, 1953).

APPARATUS

Many types of sets for the collection and giving of blood are available, and progress is being made on an international plane to secure at least functional interchangeability of transfusion apparatus. This is most simply accomplished by using a closure of self-sealing rubber for the blood bottle and appropriate piercing needles for the blood collecting and giving sets. The use of a similar closure for other fluids such as salines or plasma substitutes greatly simplifies intravenous therapy. A fine mesh filter capable of filtering at least two bottles of stored blood and a dripper of such design that 40 drops to the minute secure the transfusion of one pint of blood (560 millilitres) in four hours, should be included in the giving set. Siliconed apparatus is required for the transfusion of blood platelets. Methods for its preparation have been described by Hirsch and Gardner (1952), Tullis and Rochow (1952), and Stefanini and Dameshek (1953).

COLLECTION OF BLOOD

Donors should be healthy adults between the ages of 16 and 65 years, who have no history of anaemia, diabetes, cardiac, pulmonary or renal disease, syphilis, jaundice, or malaria (within the past two years). Hepatitis may be transmitted by transfusion of blood from a donor many years after he has suffered from the disease. Blood should not be taken from a donor who has recently been in contact with a case of infectious disease and who may be incubating the infection. The blood of donors with allergic disorders, or those in whom more than two years have elapsed since an attack of malaria, may be collected for the preparation of plasma. The donor's haemoglobin level should be checked, and donation refused if it is below 12·5 grammes per cent (85 per cent Haldane) Donors should rest under supervision for at least twenty minutes before returning to normal duties, and replacement of the blood lost is hastened by taking additional iron salts, for example, 3 grains (0 2 gramme) of Tabellae Ferri Sulphates three times a day during the following seven days. This is of particular importance in the case of female donors of child-bearing age if they give blood regularly, as they may otherwise suffer an iron depletion.

ROUTES AND TECHNIQUES OF ADMINISTRATION

The majority of transfusions are administered through a needle inserted into a limb vein "Cutting-down" and tying in a cannula should be avoided whenever possible, especially in those receiving multiple transfusions.

Intra-arterial transfusion

Resuscitation of moribund patients, who have not responded to intravenous transfusion, has been reported following intra-arterial transfusion (Devitt and Wigderow, 1951, Good, 1953) It is claimed that the blood flow through the coronary and the cerebral circulations is more rapidly and effectively restored by this route, as well as the filling of the whole arterial tree.

A needle is inserted usually into the radial or femoral artery with the end directed towards the heart, but transfusions have also been given directly into the aorta, particularly during abdominal or thoracic operations (Haxton, 1953; Stephenson and Hinton, 1953). The giving apparatus should include a pressure pump (a sphygmomano-

meter bulb is suitable in emergency), and a manometer so that the blood may be injected at normal arterial pressure. All joints in the equipment must be firm, and a safety float valve is an additional safeguard against air embolism. The blood used must be free of clots, otherwise emboli may lodge in peripheral vessels. Arterial spasm is not uncommon when a limb vessel is used, and gangrene of the extremity has been reported as an occasional complication. The risk of gangrene is also increased if the artery is cannulated. Only blood should be transfused by the intra-arterial route; infusion of a non-oxygen-carrying fluid produces a rapid anoxia of the tissues. The danger of hyperkalaemia is avoided by using blood not older than seven days.

Intra-arterial transfusion should be restricted to the treatment of patients who have suffered a considerable reduction of circulating blood volume and who have failed to respond satisfactorily to transfusion by the intravenous route. The equipment should be immediately to hand during any operation in which there is a risk of uncontrollable and massive haemorrhage.

Control of speed of administration

Slow drip transfusions require careful supervision if the speed of flow is to remain constant. A "drip-rate" record should be kept by the nursing staff and any necessary adjustments should be made promptly. The flow may vary because of movements of the needle, changes in temperature of the limb, and relaxation of an initial venous spasm. Prolonged spasm may be relieved by the intravenous injection of 1 per cent procaine in doses up to 10 millilitres.

Increasing the height of the bottle above the vein, together with the use of a giving needle of wide bore (for example, 24/10 gauge) will often enable a sufficiently rapid transfusion to be given to a case of severe oligaemia. When greater speed is required, the pressure within the bottle may be raised by a sterilized Higginson's syringe, or a sphygmomanometer bellows. A cotton-wool air-filter should be included in the tubing attaching the pump to the air-inlet needle of the transfusion set, to prevent bacterial contamination of the transfusion fluid (Bull and Hurst, 1953).

Air embolism

The possibility of air embolism must be considered when positive pressure is applied to increase the rate of transfusion. If the type of giving set used has a filter inside the bottle this may become partially blocked with clot, preventing the outflow of blood, but permitting the entry of air into the giving tubing. Therefore, pressure must be released as soon as the level of the fluid in the bottle reaches the top of such an internal filter. Positive pressure should be applied only by the doctor supervising the transfusion and not by the nursing staff.

Use of polythene tubing

Polythene tubing, which is available in diameters of 0·5, 1·0, 1·5 and 2·0 millimetres, may be used for the cannulation of a vein. Tubing of finest bore may be threaded into the vein through a wide bore transfusion needle, thus avoiding cannulation. The tubing may be inserted for several inches into the lumen of the vein, or via a peripheral vein into one of the major venous channels, so that it does not irritate the vein or become easily dislodged. It is then connected by a suitable adaptor to the transfusion giving set.

TRANSFUSION IN SPECIAL CONDITIONS

The effects of injury

Recent studies (Grant and Reeve, 1951; Clarke, 1952) have confirmed the importance

of blood loss, externally or internally in the injured area, as the most important cause of so-called "traumatic shock." Vasoconstrictive mechanisms are evoked to help maintain blood pressure in the presence of a low blood volume, and if prolonged may result in irreversible tissue changes, particularly in the kidneys, liver and brain. Assessment of the extent of blood loss and, where necessary, its replacement as accurately and as soon as possible are therefore of paramount importance. Significant blood loss in civilian injuries is most commonly associated with major fractures and with injuries of the trunk (Clarke, 1953). A single major fracture is associated with a depletion of blood volume of about 1 litre, two major fractures 1–2 litres A patient with fractures of the pelvis associated with visceral injuries may have lost 2·5–3·5 litres into the damaged areas, that is about 50 per cent of the total blood volume (Noble and Gregson, 1946). Although the blood pressure usually falls proportionately with the reduction in blood volume, it is sometimes well maintained when gross haemorrhage is known to have occurred A fall in systolic pressure to below 100 millimetres of mercury indicates a blood volume depletion of at least 30 per cent or 1 5–2 litres (Grant and Reeve, 1951) and calls for prompt transfusion. It is equally important, however, to anticipate and prevent circulatory collapse by early and adequate transfusion, and this should be given to a patient with severe trunk or limb injuries, or one who has clearly suffered a severe haemorrhage, even if the blood-pressure is normal. Pallor of the lips, and a general restlessness are valuable signs and commonly indicate a blood volume depletion of at least 40 per cent.

Transfusion should be given at a rapid rate (100 millilitres per minute) until the systolic pressure has reached a normal level and there is a general clinical improvement. In severe cases a faster rate may be attained by using several veins, but when the condition appears desperate or no clinical progress is made, blood should be transfused under pressure into an artery. Transfusion should be maintained during operation at a steady drip rate, accelerated to cover any further bleeding, and continued in the post-operative period for as long as there is any subsequent blood loss. Citrated blood is the fluid of choice, but plasma or plasma substitute are of value when blood is not immediately available. They may be transfused in the proportion of 1 bottle to 2 of blood. The pre-operative haemoglobin level should not be less than 10 4 grammes per cent (70 per cent Haldane). Over-transfusion is avoided by watching carefully the patient's neck veins, and slowing or discontinuing the transfusion if congestion develops. The chief risk is in injured elderly arteriosclerotic patients, and in patients with significant thoracic injuries.

Haemorrhagic states

A deficient prothrombin level, with a consequent tendency to bleeding, spontaneously or during operation, may be encountered in obstructive jaundice, biliary fistula, conditions in which there is extensive damage to the liver, polyposis, ulcerative colitis, sprue, other steatorrhoeas, and as the result of the excessive administration of coumarin derivatives, salicylates and aspirin. Vitamin K_1 is of value administered intravenously, but transfusion of fresh blood may be required to bring about immediate restoration of prothrombin, particularly when there is damage to liver cells.

Patients with essential thrombocytopaenia who are to be treated by splenectomy should be transfused with blood collected into ... [illegible]

a polycythaemic donor with siliconed syringes.

Bleeding in haemophilia should be treated by the transfusion of fresh blood. Liquid plasma, separated from blood within 24 hours of collection, is a satisfactory alternative fluid when previous transfusions have stimulated immune blood group antibodies, and may be stored at minus 10° C. until required for transfusion. Anti-

haemophilic globulin is present in preparations of human fibrinogen, and 10 millilitres of 2 per cent fibrinogen solution given *intravenously may* be effective in arresting bleeding temporarily. After repeated injections the patient may become refractory, and may be shown to have developed neutralizing antibodies (*Craddock and Lawrence*, 1947). Such cases are thereafter refractory to transfusions with citrated blood or plasma, but blood collected into heparin may arrest haemorrhage (*Van Crevald and* Paulssen, 1952). A prophylactic transfusion of at least 1 litre of whole blood or 500 millilitres of plasma should be given whenever operation is necessary in a haemophilic subject, but Biggs and MacFarlane (1953) have warned that no form of therapy yet available can be relied upon to cure even temporarily the haemostatic defect, and major surgery is to be avoided unless it offers the only hope of survival.

Stored blood appears to be more effective than fresh in arresting haemorrhage in cases of Christmas disease, a recently described bleeding diathesis previously confused with haemophilia (Biggs and colleagues, 1952).

Haemolytic anaemia

The plasma of patients with acquired haemolytic anaemia, who may have to be treated by splenectomy, often contains immune auto-antibodies which will haemolyse a high percentage of donor bloods. Special care must therefore be exercised in the selection of blood for transfusion, and the blood tested for compatibility by an *indirect anti-globulin (Coombs) test.*

Pre-operative and post-operative transfusion

The condition of under-nourished or anaemic patients who have to submit to operation may be improved by pre-operative transfusion. Besides anaemia, some degree of hypoproteinaemia may be present. Hypoproteinaemia may cause decreased gastro-intestinal *motility, abnormal oedema at the site of gastro-intestinal anasto*moses, pre-dispose to pulmonary oedema, and retard wound healing by inhibiting *fibroblastic proliferation. Haemoglobin deficiency will also retard wound repair,* and increase the dangers of anaesthesia Severe anaemia is accompanied by a compensatory reduction in blood volume, which pre-disposes to an accelerated collapse following haemorrhage. Anaemia should be combated by transfusion of concentrated red cells so that the haemoglobin is raised above 10 4 grammes per cent (70 per cent Haldane). Hypoproteinaemia is better corrected by protein feeding, but the patient will not respond satisfactorily until any co-existing anaemia has been treated (Whipple and Robbins 1951). Pre-operative transfusions should be given several days in advance [illegible] of transfusion can accrue to a patient by increasing the [illegible] *grammes per cent* (80 per cent Haldane) to 13·3 grammes per cent (90 per cent Haldane) by a pre-operative transfusion, and this treatment should be used for the correction of marked anaemia only Reactions to transfusion may be masked, and consequently the effects more severe, in the anaesthetized patient. Transfusion during operation should be reserved strictly to correct significant blood loss therefore and not permitted to become part of a surgical ritual.

Anaemia and hypoproteinaemia may develop post-operatively in those in whom the gastro-intestinal tract has been *operated upon, and in cases of severe burns* or trauma. They should be countered by the transfusion of blood or plasma in amounts sufficient *to raise the haemoglobin above* 10 4 grammes per cent (70 per cent Haldane) and the plasma proteins above 6 grammes per cent. Blood should not be transfused during convalescence except to correct an intractable anaemia, and the employment of transfusion to hasten the turnover of hospital beds is to be deprecated.

COMPLICATIONS OF TRANSFUSION

Complications following transfusion may be of four types: (1) Pyrexial; (2) haemolytic, (3) circulatory; and (4) delayed.

Pyrexial

A sharp rise in temperature heralded by a rigor occurs as a complication of 1–2 per cent of transfusions The frequency is related to the care taken in the preparation of transfusion apparatus, exclusion of pyrogens, and the storage and selection of blood and blood products, including the sensitivity of direct matching tests. Patients receiving repeated transfusions show an increased tendency to pyrexial reactions despite careful direct matching, and some have developed a sensitization to plasma factors (Dameshek and Neber, 1950). Concentrated red cells well washed in saline to remove all traces of plasma may be better tolerated, and anti-histamines before the transfusion may be of value.

Haemolytic reactions

As a result of the work of Muirhead and his colleagues (1948), Borst (1948), and Bull and his colleagues (1949), there is an improved recovery rate in patients suffering renal failure following haemolytic transfusion reactions. The essential lesion is an acute necrosis of renal tubules, which will be aggravated by prolonged hypotension, anoxaemia, alkalosis and salt and water imbalance. Immediately an incompatible

should be given, or one litre of 10 per cent glucose in distilled water infused intravenously. In the absence of a satisfactory urinary output following these measures, treatment is instituted for renal failure. A polythene stomach tube is passed and the following mixture administered by slow drip during each subsequent twenty-four hours dextrose, 400 grammes, peanut (or olive) oil, 100 grammes; acacia, sufficient to emulsify, water to one litre. This mixture provides sufficient calories to prevent tissue breakdown, with liberation of potassium, and sufficient water to cover the loss through the skin and lungs (Bull and his colleagues, 1949) If vomiting or diarrhoea is troublesome the oil may be reduced to 25 grammes. The volume of any urine passed should be measured and an equivalent volume of the following fluid added to the basic intake to cover the urinary loss of water and electrolytes: NaCl, 3·5 grammes; $NaHCO_3$, 1 gramme, water to 1 litre. Should the patient vomit, water and electrolyte loss by this route is prevented by returning the vomit, filtered through lint, *via* the stomach tube This regime should be continued for two days after a diuresis exceeding one litre per day has occurred. Drastic procedures such as renal decapsulation or splanchnic block will not hasten the onset of the diuresis, and are unjustifiable and dangerous The use of an artificial kidney, or peritoneal dialysis, is not required unless the patient's serum potassium has risen to a dangerously high level. A good oxygen supply to the damaged kidneys is essential, and if the patient is anaemic, concentrated red cells should be transfused to raise the haemoglobin to at least 10 4 grammes per cent (70 per cent Haldane). Infection is prevented by administering 1 mega unit of penicillin I M daily. Large quantities of water and electrolytes may be lost during the diuretic phase, which will persist for as many days as there were days of oliguria before it. During this phase the synthetic diet should be replaced by a low protein oral diet, basically fruit and fruit juices, which should provide one litre of water to cover insensible loss, together with a volume of the sodium chloride and bicarbonate solution equal to the volume of urine passed.

Circulatory

Circulatory overloading is avoided by watching carefully for filling of the jugular veins. If dyspnoea develops, the transfusion should be stopped at once, and if the patient is recumbent, he should be propped up If rapid improvement does not follow, venesection, the administration of oxygen and digoxin may be necessary.

Delayed complications

Homologous serum jaundice

Jaundice which is clinically indistinguishable from infective hepatitis may occur 40–150 days after transfusion of blood, concentrated red cells or plasma. It has been reported also following the use of certain plasma fractions (thrombin and fibrinogen). As far as is known, the case incidence following whole blood is 0·8 per cent, and after the transfusion of small-pool dried plasma about 1·5 per cent (Lehane and colleagues, 1949). Large-pool plasma carries a higher incidence and has not been prepared since 1945. Cases of homologous serum jaundice, together with the serial numbers of the bottles of blood or plasma involved, should be reported to the laboratory from which the transfusion fluid was obtained, so that carrier donors can be traced and any unused plasma of the same batch can be withdrawn.

Haemochromatosis

Increased deposits of iron may occur in patients with refractory anaemia receiving multiple transfusions and are not losing blood. These may lead to fibrosis of the liver, skin pigmentation, and fibrosis of the pancreas with severe diabetes mellitus (Schwartz and Blumenthal, 1948).

(*See also British Surgical Practice* Blood Transfusion—Practice Vol. 2, page 195, S K 62, Blood Transfusion—Thoery, Vol 2, page 210, S K 63)

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CARCINOMA OF THE OESOPHAGUS

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Carcinoma of the oesophagus is common, occurring as frequently as cancer of any other part of the alimentary tract (Parker, Hanna, and Postlethwait, 1952). Great efforts have been made during the past few years to devise effective forms of surgical treatment for this most distressing disease. The contributions of Churchill (1942) and Sweet (1949), Allison (1949), Tanner (1947), and Wookey (1947) have been outstanding. The various methods are advocated by their devisors with great vigour so that it becomes difficult for the impartial surgeon to select the technique best suited to his individual patient. Although the present writer has a particular interest in one of the methods to be described, a sincere effort will be made to give an unbiased opinion of the value and application of the various schemes. Consistency is always attractive, but although one method may be made to apply to most carcinomas of the oesophagus, an alternative method may be much more effective for a carcinoma in a particular location, or for a patient unable to withstand the most severe surgical intervention.

A brief review of the anatomy of the oesophagus, and the pathology, symptoms and diagnosis of carcinoma of the oesophagus helps to bring to focus the central problem of selecting the type of operation most suitable for the individual patient.

ANATOMY

The oesophagus commences at the crico-pharyngeal sphincter 15 centimetres below the upper teeth and continues down in the middle of the body between the trachea and vertebral bodies to the carina, then within the curl of the descending aorta and behind the left auricle to the diaphragm and for 1 centimetre beyond to the stomach. The oesophagus is most difficult of access at the junction of its upper and middle one-third, where it is enclosed laterally by the aortic arch on the left and the azygos vein on the right, and is crossed by the thoracic duct and joined by the left recurrent laryngeal nerve as they ascend into the neck Except for the small segment within the abdomen, it is devoid of a serous coat, the covering so valuable in the healing of gastro-intestinal anastomosis. The muscular coat consisting of inner circular and outer longitudinal fibres is friable and will not hold sutures under tension. It is separated from the mucous membrane by the loose submucosa which is continuous with that of the stomach and contains a rich network of lymph vessels and racemose glands. The mucous membrane lining is of stratified squamous epithelium. It is smooth and pale pink in colour in contrast to the red pebbly gastric mucosa. The oesophagus receives its blood supply from the inferior thyroid and subclavian arteries above; from the aortic arch, descending aorta and bronchial arteries in the middle; and from the left gastric and inferior phrenic arteries below. This segmental plan of blood distribution must be kept in mind when performing an oesophageal anastomosis. The blood supply may be precarious between the segments when the lower vessels have been

divided in mobilizing the tumour. For this reason an anastomosis should be performed either close below the aortic arch where the blood supply to the oesophageal stump is maintained by the aortic and bronchial arteries, or well above the aortic arch where the blood supply from the inferior thyroid and subclavian arteries becomes adequate.

The oesophageal veins drain upwards into the inferior thyroid and azygos veins. Below, they drain into the portal system through the left gastric vein accounting for the frequency of metastases in the liver.

The lymphatics in the submucosa are continuous with those in the gastric submucosa and drain into, or communicate freely with, the cervical, peritracheal, carinal, peribronchial, left gastric, supra-pancreatic and coeliac lymph nodes.

The thoracic duct does not appear to drain the oesophagus, except possibly its lower extremity, but is liable to injury during oesophageal surgery as it travels up between the oesophagus and the vertebral bodies, and especially where it curves forward to the left of the oesophagus and ascends into the neck to empty into the left subclavian vein.

PATHOLOGY

Primary carcinoma of the oesophagus is squamous cell in type arising from the stratified squamous epithelium of the mucous membrane It may be anaplastic or well-differentiated with cell nests.

Adenocarcinoma involving the lower oesophagus is an extension of a carcinoma arising in the cardiac end of the stomach and spreading upwards for great distances in the submucosa. Rarely, an adenocarcinoma may arise in an island of ectopic gastric mucosa occasionally found in the oesophagus.

Carcinoma of the oesophagus may spread in the lymphatics of the submucosa, directly to neighbouring organs, to regional or distant lymph nodes or by the blood stream The first spread is in the submucosa and may be found microscopically two or three centimetres beyond the margins of the tumour as it appears in gross examination *Consequently, if a surgical cure is sought, the resection should be five or six* centimetres beyond the gross tumour The temptation to compromise with this ideal may be great because of the extra work and risk of a high anastomosis. In addition, the elasticity of the oesophagus may delude the surgeon into believing that his resection is adequate when actually it is dangerously close to the cancer.

Direct extension of an oesophageal carcinoma may occur early and involve the trachea, bronchi, aorta, or vertebrae, and render removal difficult or impossible.

The regional lymph nodes are often involved early in the disease. Sweet (1949) reports lymph node invasion in 70 per cent of his operated cases. Distant nodes may be involved even where the primary tumour is small and located at the opposite end of the oesophagus. The cervical nodes deep in the angle between the sternomastoid muscle and the clavicle and the left gastric lymph nodes both seem particularly vulnerable to such long-range attack.

Blood stream dissemination is common in adenocarcinoma of the cardio-oesophageal junction by way of the coronary vein of the stomach and the portal vein to the liver

About one half of the carcinomas of the oesophagus are located in the middle third, the least accessible segment, closely surrounded by vital structures which often become involved by direct extension of the tumour rendering resection impossible (Wu and Loucks, 1951). Carcinoma involving the oesophagus above the aortic arch is comparatively rare. Squamous cell carcinoma of the lower oesophagus and adenocarcinoma of the cardio-oesophageal junction together occur with about the same frequency as carcinoma of the middle third and just about equal each other. However, the surrounding structures such as diaphragm, spleen and pancreas may be sacrificed making resection possible more often than for tumours in the middle third.

SYMPTOMS

Unfortunately, the symptoms of an early carcinoma of the oesophagus may be slight and considered by the patient as not important. He may notice no more than a feeling of fullness in the neck or behind the sternum. Difficulty in swallowing solid foods may be the first symptom The patient may be able to point to the spot beneath the sternum where the food sticks, localizing the lesion with surprising accuracy. He often complains of slight pain in the area as he washes the food beyond the obstruction with a drink of water, or he may be forced to strain and regurgitate the offending piece of undigested food, sometimes accompanied by a streak of blood. Excess of mucus in the mouth and oesophagus is a common complaint, especially first thing in the morning, and the victim may find difficulty in swallowing until this has been regurgitated.

A carcinoma at the cardio-oesophageal junction may be associated with vague epigastric discomfort after meals, belching of gas or heartburn. If he has previously been troubled by achalasia or a hiatus hernia, the change in symptoms may be so gradual that its serious significance is not appreciated by the patient or his physician until the carcinoma is far advanced.

Late symptoms of spread to the trachea, bronchus, mediastinal nerves and cervical lymph nodes must be looked for without waiting for them to arise.



FIG 96 — Barium swallow. In one oblique view (*a*) there is little to suggest oesophageal cancer, but *in view (b) a definite filling defect is evident at* the junction of the lower and middle third of the oesophagus

DIAGNOSIS

Vague symptoms of cervical or retrosternal fullness or accumulation of mucus in the throat, call for a barium swallow at least. If these symptoms persist on medical *treatment for more* than a fortnight, or if there is dysphagia, oesophagoscopy should be performed even with a negative radiological report. Either barium swallow or oesophagoscopy alone may give false negatives. Fortunately it is rare for both methods of examination to be negative, in the same patient, when they are carefully performed.

Radiological examination may fail to reveal a small carcinomatous nodule or ulcer unless taken at exactly the correct angle (Fig. 96) It is never complete without examination, in the *Trendelenburg position* to fill the cardiac end of the stomach, to exclude carcinoma at the cardio-oesophageal junction.

Oesophagoscopy, when carefully performed, will reveal the small carcinomatous nodule or ulcer. Tissue diagnosis of the nodule will be easy, but it may be impossible to obtain a positive biopsy from an ulcer. The depths of the *ulcer may be inaccessible* to the biopsy forceps and the margins show nothing but inflammatory tissue (Fig. 97).

The oesophagoscopist may encounter swollen inflamed mucosa above a carcinomatous *stricture and be unable to pass the oesophagoscope safely beyond this to obtian* a positive biopsy. Such lesions are most likely to be carcinomatous and should be explored without delay, even in the face of a negative biopsy.

Differential diagnosis

Although cancer is by far the most frequent cause of oesophageal obstruction in later life, other causes of dysphagia must be considered before major surgery.

A chronic peptic ulcer of the lower oesophagus penetrating the oesophageal wall or causing stenosis, may be indistinguishable from carcinoma by barium swallow and oesophagoscopy. The oesophagitis above a peptic ulcer or a carcinoma may prevent insertion of an oesophagoscope sufficiently far to permit a positive biopsy. Strenuous efforts on the part of the oesophagoscopist to obtain tissue from the primary lesion must be avoided as the risk of instrumental perforation is great and in either case, resection is indicated



Fig 97—Surgical specimen containing a carcinoma in the mid-oesophagus At oesophagoscopy a biopsy taken from the lower margin of the ulcer showed inflamed mucosa only Fig 106 shows pre-operative and post-operative barium swallow on the same patient



Fig 98—Barium swallow showing the typical appearance of a leimyoma of the oesophagus

Strictures of the oesophagus, when occluded by pieces of food or complicated by oesophagitis, may be confused with carcinoma. The history may suggest a congenital [illegible]

Removal of any material lodged above the stricture usually reveals normal mucosa or smooth scar. If there is oesophagitis above the stricture preventing good visualiza-

tion, a few days on a strict liquid diet will reduce the oedema allowing a good view of the lesion at repeat oesophagoscopy.

Tuberculous mediastinal lymph nodes may be adherent to the oesophagus and distort it by traction or erode into both the oesophagus and bronchus, producing a fistula. X-ray evidence of calcified lymph nodes adjacent to the lesion assist in the diagnosis. Occasionally a thoracotomy may be necessary to exclude a carcinoma.

A leiomyoma of the oesophagus gives a characteristic radiological appearance (Fig. 98). It may be shelled out of the oesophageal muscle without injury to the mucosa. Tissue diagnosis by oesophagoscopy should not be attempted since the integrity of the mucosa is valuable for healing. However, the excised tumour must be examined by quick section to determine its benign nature.

Extrinsic causes of oesophageal obstruction must be excluded, such as osteoarthritis or tuberculosis of the cervical spine, aneurysm, enlarged left auricle, mediastinal tumours or cysts, and bronchogenic carcinoma invading the oesophagus.

The Plummer Vinson Syndrome may be distinguished by the associated anaemia, glossitis and achlorhydria, but women with this condition must be examined by careful pharyngoscopy and oesophagoscopy to exclude a carcinoma which frequently complicates the syndrome.

Assessment of patient

The diagnosis is not complete until the patient's ability to tolerate operation has been assessed and it has been determined whether resection should be attempted or a palliative operation performed. The patient's age, general appearance, nutrition and [illegible] Cardiovascular disease, emphysema, or chronic [illegible] appears that he will tolerate [illegible] surrounding vital structures, and has [illegible] Extension of the primary tumour beyond the oesophageal wall may be indicated by paralysis of a vocal cord. If there is infiltration of the trachea or bronchus with fistula formation, a distressing cough on swallowing fluids is a prominent symptom. Bronchoscopy may show extension of the tumour through the bronchial wall or Lipiodol swallow may reveal a fistula. Oesophagoscopy may indicate fixation of the tumour to surrounding tissues. It will be clear, however, from what has been said already, that it may not be possible to make the final decision about operability until the lesion has been exposed.

CHOICE OF OPERATION

Palliative operation

[illegible] oesophageal junction [illegible] sfactory [illegible] astinum [illegible] the cancer and is rarely involved in its spread. [illegible] irradiated with greater intensity with less risk of mediastinitis.

Resection and reconstruction

If it appears that the patient's condition and the extent of the cancer will permit excision and reconstruction of the oesophagus, two fundamental principles must be adhered to. Resection must be performed well above the extensive spread of the carcinoma into the submucosa of the oesophagus. It should never be less than five centimetres from the gross tumour, and quick section by the pathologist at operation should confirm that excision is adequate. As a second principle, the reconstructed oesophagus should not lie where recurrence is almost certain to cause obstruction and cancel out the palliative value of operation.

The location of the cancer determines the type of reconstruction required to bridge the large defect left by adequate excision. Beginning at the cardio-oesophageal junction and working upwards, six operations that will meet the requirements have been selected here.

Total gastrectomy and Roux Y oesophagojejunostomy

Adenocarcinoma of the cardio-oesophageal junction infiltrates so far into both the stomach and oesophagus that insufficient stomach remains for a satisfactory anastomosis. Consequently, in this type of lesion, it is best to perform a total gastrectomy and partial oesophagectomy with a Roux Y oesophagojejunostomy for a few centimetres below the aortic arch (Figs. 99 and 100). The abdominal part of the incision is made first, extending obliquely from the costal margin at the eighth interspace to the mid-line 2 inches below the umbilicus. Through this the lesion and the surrounding tissues and liver are explored. If the cancer is operable, the upper end of the incision is extended across the costal cartilage and out along the eighth intercostal space. The left gastric lymph nodes must be cleanly removed along with the stomach.

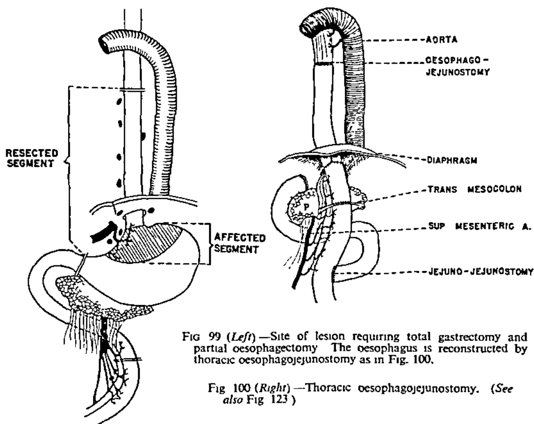


FIG 99 (*Left*)—Site of lesion requiring total gastrectomy and partial oesophagectomy The oesophagus is reconstructed by thoracic oesophagojejunostomy as in Fig. 100.

Fig 100 (*Right*)—Thoracic oesophagojejunostomy. (*See also* Fig 123)

Allison (1949) advises in addition, removal of the spleen, the tail of the pancreas, the greater omentum and a fringe of diaphragm about the oesophageal hiatus. An iso-peristaltic tube of jejunum is prepared, as described later (under *Cervical oesophagogastrostomy*) and anastomosed end-to-end with the oesophagus below the aortic arch (Fig. 100). Occasionally an adenocarcinoma of the cardio-oesophageal junction may extend so far up the oesophagus that adequate resection will necessitate anastomosis above the aortic arch. This is especially true when there is an associated hiatus hernia. The duodenal stump is closed and an end-to-side jejuno-jejunostomy performed as illustrated (Figs. 100 and 123).

Low thoracic oesophagogastrostomy

For a squamous cell carcinoma in the lower extremity of the oesc than 5 centimetres above the cardia, the oesophagus may be sectic mosed to the stomach about 4 centimetres below the aortic arch (Fi Crowding an anastomosis closer under the aortic arch than 4 centime awkward and mobilization of the oesophagus above this point jeop supply at the anastomosis.

The approach to this operation is through the bed of the seven cancer is found resectable, the diaphragm is opened by an incision ex from the oesophageal hiatus. A sharp scalpel is used and the diap and muscle cut down to the peritoneum revealing the branches of tl

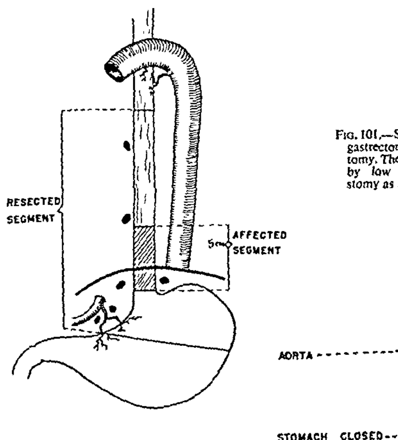
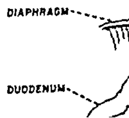


Fig. 101.—Site of les gastrectomy and tomy. The oesopha by low thoracic stomy as in Fig 1

AORTA

STOMACH CLOSED

Fig 102.—Low thoracic oesophago-gastrostomy.



which are secured before they can retract. The short gastric arteries are then divided, freeing the stomach from the spleen, and the greater omentum divided, carefully preserving the left gastro-epiploic artery and arcade (Fig. 103). The left gastric artery is then isolated close to its origin, ligated by transfixion sutures and divided, and the lymph nodes and aerolar tissue about it included in the resection, along with a generous portion of the lesser curvature of the stomach (Fig. 101). The subphrenic and para-oesophageal lymph nodes, the aerolar tissue about the tumour and a rim of diaphragm around the oesophageal hiatus must also be removed with the specimen. The stomach is divided between two crushing clamps and the upper end protected with a sponge and used to retract the oesophagus. The stomach is closed with continuous sutures of chromic catgut, an inner through-and-through layer and two invaginating layers, taking care not to sacrifice too much stomach by over-enthusiastic invagination. The mobilized stomach is then laid in the oesophageal bed up to the aortic arch, taking care not to twist it or injure the right gastro-epiploic artery. Before [illegible]

[illegible]

about two inches in diameter and must be closed, carefully avoiding injury to the blood supply of the stomach, preventing herniation of other viscera into the chest, and assisting to prevent tension on the anastomosis. The phrenic nerve may be crushed close to the diaphragm. The stomach is further anchored in position by interrupted silk sutures to the mediastinal pleura over the aorta and pericardium and to the posterior wall of the upturned oesophagus. The site of anastomosis to the stomach is then selected well within the fundus, so that the oesophagus will be

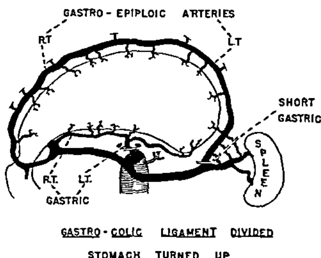


Fig. 103.—Method of assuring adequate blood supply to transplanted stomach by careful preservation of the right gastro-epiploic artery

embedded into the stomach. At this point the gastric serosa is plucked up with thumb forceps and cut off with scissors to make a circular crater down to the mucosa, about one inch in diameter. The oesophagus is attached to the margin of the crater with interrupted silk sutures closely placed and passing through the [illegible] and gastric muscle and serosa. [illegible] later identification as the row [illegible] oesophagus is then cut across about one-half centimetre from the suture line, exposing the mucosa. Since the oesophageal mucosa has a marked tendency to retract and disappear from view, it should be divided about one centimetre below the muscle incision. A large pair of angulated scissors are convenient for this purpose severing the oesophagus completely and cleanly in one cut. The gastric mucosa in the floor of the crater is then plucked up, and since it tends to be redundant rather than retractile,

Low thoracic oesophagogastrostomy

For a squamous cell carcinoma in the lower extremity of the oesophagus, no more than 5 centimetres above the cardia, the oesophagus may be sectioned and anastomosed to the stomach about 4 centimetres below the aortic arch (Figs. 101 and 102). Crowding an anastomosis closer under the aortic arch than 4 centimetres is technically awkward and mobilization of the oesophagus above this point jeopardizes the blood supply at the anastomosis.

The approach to this operation is through the bed of the seventh left rib. If the cancer is found resectable, the diaphragm is opened by an incision extending forwards from the oesophageal hiatus. A sharp scalpel is used and the diaphragmatic pleura and muscle cut down to the peritoneum revealing the branches of the phrenic artery,

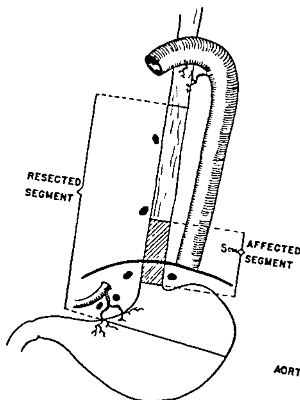


FIG. 101—Site of lesion requiring partial gastrectomy and partial oesophagectomy. The oesophagus is reconstructed by low thoracic oesophagogastrostomy as in Fig. 102.

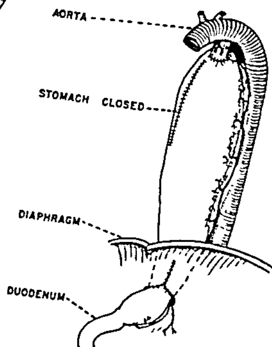


FIG 102—Low thoracic oesophagogastrostomy.

which are secured before they can retract. The short gastric arteries are then divided, [illegible] led, carefully pre- [illegible] ft gastric artery is divided, and the lymph nodes and aerolar tissue about it included in the resection, along with a generous portion of the lesser curvature of the stomach (Fig. 101). The subphrenic and para-oesophageal lymph nodes, the aerolar tissue about the tumour and a rim of diaphragm around the oesophageal hiatus must also be removed with the specimen. The stomach is divided between two crushing clamps and the upper end protected with a sponge and used to retract the oesophagus. The stomach is closed with continuous sutures of chromic catgut, an inner through-and-through layer and two invaginating layers, taking care not to sacrifice too much stomach by over-enthusiastic invagination. The mobilized stomach is then laid in the oesophageal bed up to the aortic arch, taking care not to twist it or injure the right gastro-epiploic artery. Before commencing the anastomosis the diaphragm should be sutured to the stomach and closed with interrupted silk sutures (Fig. 102). The opening in the diaphragm for the stomach should be about two inches in diameter and must be closed, carefully avoiding injury to the blood supply of the stomach, preventing herniation of other viscera into the chest, and assisting to prevent tension on the anastomosis. The phrenic nerve may be crushed close to the diaphragm. The stomach is further anchored in position by interrupted silk sutures to the mediastinal pleura over the aorta and pericardium and to the posterior wall of the upturned oesophagus The site of anastomosis to the stomach is then selected well within the fundus, so that the oesophagus will be

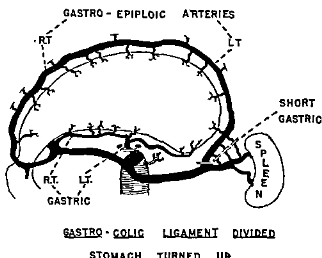


FIG 103 —Method of assuring adequate blood supply to transplanted stomach by careful preservation of the right gastro-epiploic artery

embedded into the stomach. At this point the gastric serosa is plucked up with thumb forceps and cut off with scissors to make a circular crater down to the mucosa, about one inch in diameter. The oesophagus is attached to the margin of the crater with interrupted silk sutures closely placed and passing through the oesophageal muscle and gastric muscle and serosa. The sutures at either end of this row are kept long, for later identification as the row is completed anteriorly. The muscular coat of the oesophagus is then cut across about one-half centimetre from the suture line, exposing the mucosa. Since the oesophageal mucosa has a marked tendency to retract and disappear from view, it should be divided about one centimetre below the muscle incision A large pair of angulated scissors are convenient for this purpose severing the oesophagus completely and cleanly in one cut. The gastric mucosa in the floor of the crater is then plucked up, and since it tends to be redundant rather than retractile,

a larger circle about one and one-half inches in diameter is excised. The inner invaginating line of sutures is then placed, using interrupted chromic catgut through all layers of oesophagus and stomach and continuing it anteriorly where it is completed with three or four Lembert sutures. These sutures must be closely placed, no more than three millimetres apart. If the oesophageal mucosa is missed by any one suture in this layer a leak at the anastomosis is most likely to occur. The two outer layers of interrupted silk sutures are then completed (Fig. 102), and a flap of omentum loosely tacked over the suture line.

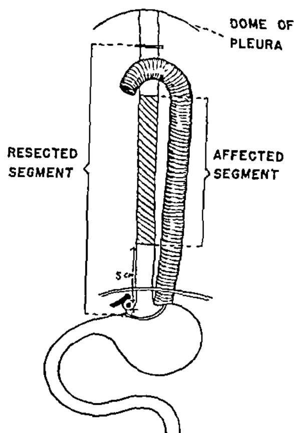


Fig. 104—Site of lesion requiring partial oesophagectomy and excision of the cardiac end of the stomach. The oesophagus is reconstructed by high thoracic oesophago-gastrostomy as in Fig 105

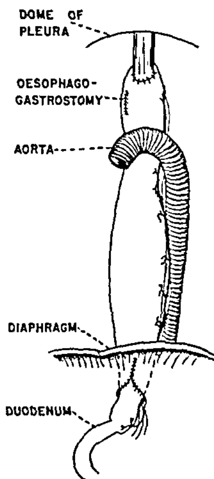


Fig 105.—High thoracic oesophago-gastrostomy.

High thoracic oesophagogastrostomy

A cancer of the oesophagus between the aortic arch and a point 5 centimetres above the cardia requires resection and oesophagogastrostomy above the aortic arch (Figs. 104 and 105). Since the blood supply of the remaining oesophagus comes from the inferior thyroid and subclavian arteries, the anastomosis is best made two or more centimetres above the aortic arch. The seventh rib is removed as in the low oesophagogastrostomy, but in order to obtain adequate exposure for the anastomosis above the aortic arch, the sixth, fifth and occasionally the fourth ribs and their intercostal bundles must be divided posteriorly. Two or three intercostal arteries must be divided to facilitate dissection behind the aortic arch. Care must be taken to identify the thoracic duct in this area and if necessary, to ligate it. Resection of this segment requires removal of the left gastric, subphrenic and para-oesophageal lymph nodes and all accessible peribronchial and paratracheal nodes. To reach this level for anasto-

mosis most of the stomach must be preserved by a very limited resection of cardia and the right gastric artery will have to be divided to free the lesser curvature (Fig. 103). The closed stomach is passed up behind the aortic arch in the old bed of the oesophagus and the anastomosis performed. When located here, the stomach rapidly becomes fixed, relieving strain on the anastomosis, and has less tendency to dilation (Figs. 106 and 122).

Cervical anastomosis.—Cancer of the oesophagus behind the aortic arch and up to within 5 centimetres of the crico-pharyngeus requires resection in the neck and reconstruction by oesophagojejunostomy or oesophagogastrostomy (Figs. 107, 108 and 116).

Cervical oesophagojejunostomy

If there are indications that a cancer in this segment (Fig. 107) has penetrated the oesophageal wall and become fixed to surrounding vital structures, it is preferable to plan a two-stage procedure At the first stage the oesophagus is reconstructed by a jejunal transplant in the anterior mediastinum using two incisions, one in the neck and one in the abdomen.

The intra-abdominal part of the procedure is carried out through a left paramedian rectus-displacing incision extending from one inch above the xiphisternal junction to one inch below the umbilicus. This incision allows easy retraction to the right of the ligamentum teres of the liver, and during the closure of the wound, facilitates the closing of the peritoneum around the jejunum as the latter passes from the peritoneal cavity to the anterior mediastinum.

The jejunum is brought out of the abdominal cavity, spread fan-wise on warm moist towels, and the distribution of the superior mesenteric artery studied (Fig. 109). The relative sizes of the first four or five branches should be noted. If the fourth or fifth branch is a large one, it means that the first three or four can be severed without jeopardizing the blood supply of the bowel, because the retrograde flow through the arterial arcade close to the intestine will be adequate This can be tested by simultaneous digital compression of the vessels chosen for division. The jejunum may then be divided near the ligament of Treitz and therefore permit the distal end to be anastomosed to the oesophagus in an isoperistaltic manner (Figs. 109 and 108).



FIG 106 —Pre-operative and post-operative barium swallow in patient with carcinoma of the mid-oesophagus for which a high thoracic oesophagogastrostomy was performed The anastomosis is above the aortic arch at the level of the clavicle Specimen shown in Fig 97

The distance from the thyroid cartilage to the region of the ligament of Treitz should be measured with a piece of tape which is kept for frequent use while preparing the jejunum. The marked tape is laid along the line of the vascular arcade of the mesentery to get an approximate idea of the length of jejunum required. The peritoneum of both sides of the mesentery of this length of jejunum is then totally removed from the root of the mesentery outward to the edge of the jejunum. This is facilitated

between them (Fig. 109). Veins must not be ligated any more freely than arteries, for venous drainage is just as important as arterial supply.

The tube is then measured on the anterior chest wall and must reach the thyroid cartilage easily if a secure anastomosis is to be made without the least tension on the mesenteric vessels. Two of our patients died of post-operative gangrene of the jejunal tubes which had a good circulation before being passed into the neck. Traction on the mesenteric vessels was responsible. At this point in the operation one must decide

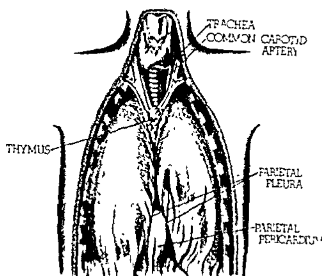


FIG. 111.—Anatomy of anterior mediastinum, the anterior chest wall having been removed.

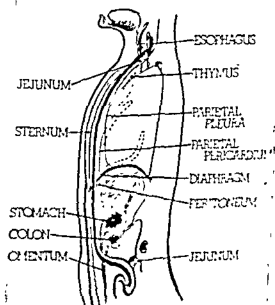


FIG. 112.—Sagittal section illustrating location of jejunal transplant in anterior mediastinum.

whether the prepared tube of jejunum is viable. It must have a good colour and show at least a faint pulsation at the end of the arterial arcade. In 2 out of 17 of our cases, preparation of a viable tube was impossible because of an incomplete arcade. If such a condition is found the attempt must then be abandoned, the tube amputated and the continuity of the jejunum re-established by end-to-end anastomosis.

Having prepared the jejunum for its transposition, considerable time is saved by continuing the operation as two surgical teams. One team completes the abdominal

part of the procedure, while the other team exposes the oesophagus in the neck and does the oesophagojejunostomy.

From the abdomen, the anterior mediastinum is entered through the anteromedial gap of the diaphragm, by *blunt dissection upward and to either side, close to the deep*

entire hand to enter the anterior mediastinum. Blunt dissection with the fingers is gently carried upward anterior to the pericardial sac, carefully pushing both pleural reflections laterally (Figs. 111 and 112). No troublesome haemorrhage has been encountered during this procedure. Gradually the hand is worked upward until the second two fingers appear in the neck incision.

The cervical incision is made along the anterior border of the left sternomastoid muscle well down over the episternal notch. The left side is chosen as the lower cervical oesophagus deviates slightly to the left. The deep fascia is then opened down

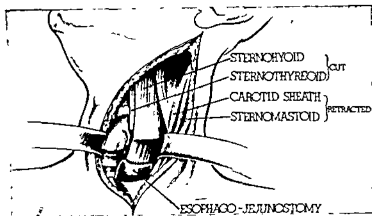




FIG 113 (*Above*) —Jejunum anastomosed to oesophagus in the neck.

FIG 114 (Right) —Autopsy specimen from patient who died one year following palliative cervical oesophagojejunostomy. Note level and quality of anastomosis

into the suprasternal space, the left strap muscles divided, and the oesophagus approached between the trachea and the carotid sheath (Fig. 113). The recurrent laryngeal nerve is then identified and protected and the cervical oesophagus freed *from the trachea and cervical spine and drawn up into the wound The oesophagus is* clamped with slotted forceps below, narrow forceps above, divided, and the stumps carbolized The distal stump is then sutured with continuous chromic catgut through the slotted forceps and invaginated with an additional layer of interrupted black silk.

The anterior mediastinum is then tunnelled with the fingers from above, keeping close to the sternum and separating the inner part of the insertion of the sternothyroid muscle. Space should be made to admit three fingers. The jejunal tube is then laid out on the chest and the segment to be transplanted straightened out as far as possible and a marker suture placed in the bowel wall indicating the amount of actual intestine, rather than mesentery, required to reach the neck. This is to prevent the passage of redundant loops of jejunum into the mediastinal tunnel.



FIG. 115 —Barium swallow following cervical oesophagojejunostomy.

The long ends of the heavy silk tie on the proximal end of the jejunum to be transposed are now passed up through the anterior mediastinum and the jejunum very carefully drawn upward. Great care is taken not to pull on the mesentery of the bowel for fear of injuring an artery or vein. The jejunum is pushed up through the mediastinum rather than pulled, and the silk ligature used as a guiding string.

Excess length of jejunum is excised and the upper oesophagus divided above the narrow clamp. The oesophagus and jejunum are then anastomosed meticulously end-to-end with two layers of interrupted invaginating sutures placed 3 millimetres apart. For the inner layer, 0 chromic catgut is used through all layers of the gut and securing a good bite of the oesophageal mucosa. The outer layer is of 0 black silk and so placed as to invaginate the oesophagus into the jejunum. The wound is then lightly powdered with sulphathiazole-penicillin mixture and closed with a Penrose drain (Fig. 114).

Meanwhile an end-to-side anastomosis has been made between the short stump of jejunum left beyond the ligament of Treitz and the side of a convenient portion of jejunum (Fig. 108).

A gastrostomy is made, using a mushroom catheter and bringing the catheter out two or three inches lateral to the paramedian incision.

The peritoneum is loosely closed around the jejunum as the latter enters the anterior mediastinum opposite the marker suture, to prevent excess jejunum sliding up into the chest. The rest of the wound is closed in the usual manner.

The patient is fed intravenously for three days after operation, when gastrostomy feedings are commenced. Gastric suction is applied immediately to avoid distention. Clear fluids are allowed by mouth after the second week and soft foods and solids after the third week (Fig. 115).

At the second stage a few weeks later, the right chest is explored and the oesophagus freely exposed by resection of the overlying azygos vein. If excision is possible it may be done safely and cleanly through this approach and the remaining oesophagus and regional lymph nodes excised. If the cancer has spread too far for removal the wound is closed and intensive deep x-ray therapy commenced.

Cervical oesophagogastrostomy

If the tumour in this area (Fig. 107) appears to be small and not adherent to the surrounding vital structures, it should be possible to mobilize it by an approach through the left chest and neck and to reconstruct the oesophagus by cervical oesophagogastrostomy. The stomach must be further mobilized to reach the neck by incising the peritoneum to the right of the duodenum, which is freed by blunt dissection. The cervical incision is as described for cervical jejuno-oesophagostomy. The oesophagus is freed by dissection through the neck and chest avoiding injury to

the recurrent laryngeal nerves and thoracic duct. The stomach is divided as for a high thoracic anastomosis and the closed stomach passed into the neck beneath the aortic arch in the bed of the oesophagus, and the anastomosis performed (Figs. 116 and 117).

As opposed to cervical oesophagojejunostomy, this operation has the advantage of a one-stage procedure and preserves gastric function, but the patient must be in unusually good condition to survive so much trauma at one time. The removal of a tumour in the least adherent to surrounding tissues is far more difficult by this approach than through the right chest, and the regional lymph nodes cannot be excised completely. Finally, if the cancer is found to be inoperable the wound must be closed without securing the advantage of a palliative operation. In summary it may be stated that cervical oesophagogastrostomy should be reserved for the younger patient in good condition with a small early cancer confined to the oesophagus.

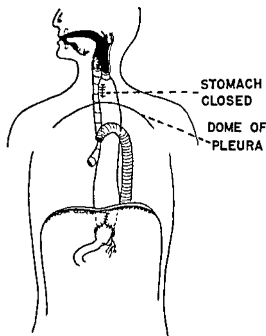


Fig 116—Cervical oesophagogastrostomy for lesion located as in Fig 107.



Fig 117—Barium swallow taken two years [illegible]

the aortic arch and anastomosed to the oesophagus at the level of the clavicle

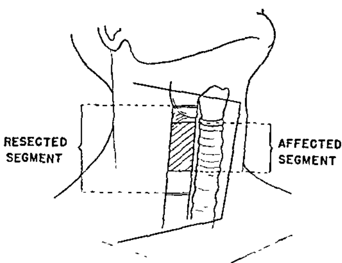


FIG. 118.—Site of lesion requiring partial oesophagectomy. The oesophagus is reconstructed with a cervical skin tube as in Figs 120 and 121.

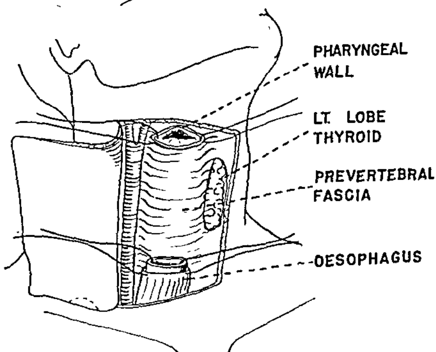


FIG. 119.—Wookey operation (*a*)

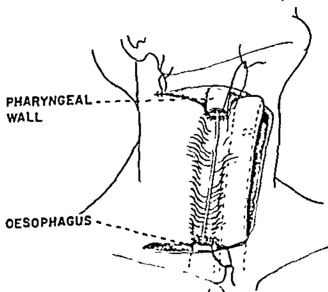


FIG. 120.—*Wookey operation (b).*

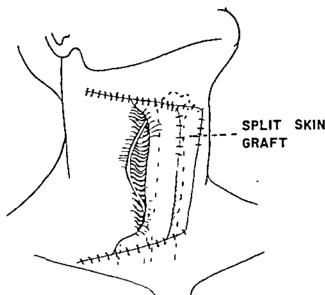


FIG. 121 —Wookey operation (c)

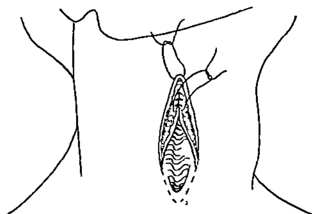


FIG 122 —Wookey operation (d)

Wookey operation (reconstruction of the cervical oesophagus by a skin tube)

A cancer of the upper oesophagus not more than 5 centimetres below the cricoid cartilage and not involving the larnyx may be treated by excision of the upper oesophagus and reconstruction by a skin tube. A large rectangular flap of skin, with a broad base, is raised on the same side of the neck as the tumour (Fig. 118) The flap should include subcutaneous fat, platysma and the upper part of the sternomastoid muscle, which carries most of the blood supply to the skin. Recently Grimes and Stephens (1952) have added to this procedure block dissection of the cervical lymph nodes on the same side of the neck, an important contribution in view of the frequency of spread to the regional lymph nodes. The strap muscles are then divided, the recurrent laryngeal nerve identified and protected, and the thyroid lobe of the affected side resected. The oesophagus is approached between the carotid sheath and the trachea, below the tumour, and freed from the trachea, larynx and surrounding tissues up and about the wall of the hypopharynx. The segment of oesophagus bearing the cancer is then excised including at least 3 centimetres of normal oesophagus below and 3 centimetres of normal oesophagus and hypopharyngeal wall above (Fig. 119). The prepared flap of skin is then folded into the bed of the oesophagus and held in place by a few interrupted chromic catgut sutures to the prevertebral fascia. A small elliptical part is removed from the margin of the flap, where it will be sutured to the stump of the oesophagus, in order to increase the size of the stoma The skin flap is



FIG 123 —Barium swallow two months following total gastrectomy and Roux Y oesophagojejunostomy for a large adenocarcinoma of cardio-oesophageal junction (*see* Figs. 99 and 100)

sutured circumferentially to the wall of the hypopharynx above, and to the stump of the oesophagus below with interrupted sutures of black silk, closely placed (Fig. 120). The raw surface left where the skin flap fails to reach its origin is covered with a split skin graft (Fig. 121). A tracheotomy should be done and the tube left in place until the post-operative oedema of the larnyx has subsided. A Levine tube is inserted through the nose and passed along the reconstructed trench into the oesophagus to the stomach for feeding. About five weeks later, when a good collateral blood supply to the graft has been established, the trench is closed and the reconstruction completed (Fig. 122).

When the larynx is involved it must be included in the resection and a permanent tracheotomy made A somewhat larger flap of skin is elevated and the lymph nodes on the affected side of the neck removed by block dissection. The near lobe of the thyroid is removed along with the isthmus and the opposite lobe separated from the trachea and preserved along with the parathyroid. The trachea is divided below the cricoid, or lower, depending on the extent of the lesion and is exteriorized in the suprasternal notch and intubated with an endotracheal catheter, with an inflatable cuff, for anaesthesia. The oesophagus is transected at the same level, dividing the muscle at about 1 centimetre lower than the mucosa and controlling the stump with traction sutures (Fig. 119) A transverse incision is made into the hypopharynx through the thyrohyoid membrane and the necessary upper level of resection determined. Beginning the dissection from below, the entire block of tissue, including the upper oesophagus and trachea, larynx and hypopharynx, is then freed from the prevertebral fascia and carotid sheaths The wall of the hypopharynx is transected at the appropriate level and the specimen removed The oesophageal defect is repaired as described previously.

Finally the tracheal stump is sutured to the skin to form a permanent tracheotomy and a tracheotomy tube inserted.

RESULTS

The following six tables give the results in my own small series of cases. They are of most value in indicating the pitfalls of the past and in planning safer and more effective individualized treatment for future patients afflicted with this terrible disease.

TABLE I

CANCER AT CARDIO-OESOPHAGEAL JUNCTION

No	Operation	Survival
16		
8	Not resectable	
4	Palliative cervical jejuno-oesophagostomy	1 year 6 months 3 days 11 days
4	Partial gastrectomy and low thoracic oesophagogastrostomy	2 months 6 weeks 2 years Alive and well, 2 mos post-op.

Although symptoms may be inconspicuous or appear late from cancer in this area, an earlier

TABLE II

CANCER OF LOWER OESOPHAGUS (WITHIN 5 CENTIMETRES OF CARDIA)

No	Operation	Survival
11		
3	Not resectable	
6	Low thoracic gastro-oesophagostomy	Alive and well, 6½ yrs, post-op 5 days 16 months Alive and well, 2 yrs, post-op. 5 months Alive and well, 3 mos post-op
2	Palliative cervical oesophagojejunostomy	8 days 4 months

TABLE III

CANCER OF OESOPHAGUS BETWEEN AORTIC ARCH AND POINT 5 CENTIMETRES ABOVE CARDIA

No	Operation	Survival
15		
6	Not resectable	
4	High thoracic gastro-oesophagostomy	2½ years Alive and well, 2 yrs. post-op. Alive and well, 4 mos post-op. Died post-op
5	Palliative cervical jejuno-oesophagostomy	5 weeks 2 months 3 days 16 months 3 weeks

TABLE IV

CANCER OF OESOPHAGUS BEHIND AORTIC ARCH AND UP TO WITHIN 5 CENTIMETRES OF CRICO-PHARYNGEUS

No	Operation	Survival
4		
2	Cervical oesophagojejunostomy and oesophagectomy	14 months 9 months
1	High thoracic gastro-oesophagostomy	6 months
1	Palliative cervical oesophagojejunostomy	1 year

The patient treated by high thoracic gastro-oesophagostomy died 6 months after operation from recurrence at the *anastomotic site*. A cervical oesophagojejunostomy or oesophagogastrostomy should have been performed

The 2 patients treated by cervical oesophagojejunostomy and oesophagectomy had cancers which could only be separated from the trachea by sharp dissection [illegible] from local recurrence o [illegible] gectomy was performed [illegible] to resect the involved ar [illegible]

TABLE V

CANCER OF UPPER OESOPHAGUS (WITHIN 5 CENTIMETRES OF CRICO-PHARYNGEUS)

No	Operation	Survival
3		
2	Not resectable	
1	Wookey operation	7 months

TABLE VI

OPERATIVE MORTALITY

No.	Operation	Survival
12	Palliative operations with 5 deaths	41 per cent
18	Resections with 2 deaths	11 per cent

CONCLUSION

The surgical treatment of cancer of the oesophagus is at an early stage of development and the results have been correspondingly poor. This should not be too discouraging, for surgical techniques permitting more radical resection of the cancer are commencing to give improved results.

As the medical profession at large becomes aware of the possibility of a surgical cure, more cases will have an early diagnosis and be found resectable.

(*See also British Surgical Practice* Oesophagus, Vol. 6, page 314, S. Key 247.)

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TABLE IV

CANCER OF OESOPHAGUS BEHIND AORTIC ARCH AND UP TO WITHIN 5 CENTIMETRES OF CRICO-PHARYNGEUS

No	Operation	Survival
4		
2	Cervical oesophagojejunostomy and oesophagectomy	14 months 9 months
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1	Palliative cervical oesophagojejunostomy	1 year

The patient treated by high thoracic gastro-oesophagostomy died 6 months after operation from recurrence at the anastomotic site. A cervical oesophagojejunostomy or oesophagogastrostomy should have been performed

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TABLE V

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No.	Operation	Survival
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CARCINOMA OF THE STOMACH

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The opinion has been expressed at various times that, owing to the nature and mode of spread of gastric cancer, surgery had reached its zenith of achievement and that more improvement in the results of surgical treatment was not to be expected. It is true that cancer of the stomach is unchanged in its insidious onset and its malignant progress, yet the average chances of a five-year survival for sufferers from the disease have appreciably increased during the last ten years. There are several causes of this improvement, but in the main it has been due to the diminished operative mortality resulting from. (1) Improved anaesthesia, (2) the use of chemotherapy and antibiotics; and (3) improved technique and care of the patient during and after operation. These matters will be discussed later.

DIAGNOSIS OF GASTRIC CANCER

Because most cases of gastric cancer are advanced when first exposed at operation, and because there is probably a time in the course of each case when the lesion is entirely local, completely removable and probably curable, much thought has been given to the possibility of getting cases to the surgeon earlier. This requires improvement at three stages; the first is to get the patient to his doctor earlier; the second is that the doctor should keep the possibility of cancer well forward in his mind; and the third is that more reliable methods of diagnosis of cancer of the stomach should be provided.

Symptoms

The patient comes to the doctor late partly because cancer is almost symptomless at its onset, unless it causes obstruction, or an accident such as haemorrhage or perforation, even in its later stages there may be slight symptoms, such as diminished appetite, epigastric fullness, nausea, weight loss. These symptoms are too vague to be usefully drawn to the attention of the general public. Indeed, it is notable that medical men and nurses come no earlier with their gastric cancers than other people.

A method of diagnosis

In an endeavour to bring the possibility of gastric cancer forward in the doctors' minds, a change in the normal logic of diagnosis is advocated. It is recommended to the general practitioner that, when a patient of cancer age presents himself with symptoms which could be attributed to gastric cancer (for example, upper abdominal discomfort, particularly if associated with meals; vomiting; anorexia; pallor; and weakness) he should be regarded as a case of gastric cancer until the stomach is proved to be free of growth It might be added that once the stomach is shown not to harbc [illegible] doctor's duty [illegible] nset to gastric cancer, for example, colonic or bronchial carcinoma, [illegible] g to the customary, orthodox and more leisurely approach to diagnosis.

Aids to diagnosis

There have been no great advances in methods of diagnosis of carcinoma of the

stomach since the publication of *British Surgical Practice*. Certain special aids to diagnosis may, however, be mentioned.

Cytological examination of gastric contents

The first is by cytological examination of the aspirated gastric contents. This method in the past has been too unreliable to be of much value. Improvements in the collection of gastric aspirate have been made and Panico, Papanicolaou, and Cooper (1950) have even recommended the use of an "abrasive balloon", a balloon made abrasive by fitting a fine silk veil to its exterior; it is attached to the end of a double lumen tube (Fig 124). After introduction into the stomach it is carried to the pylorus by peristalsis and then drawn up to the cardia again several times in order to dislodge cells from the stomach or tumour into the gastric lumen whence they can be aspirated and examined. Special methods of fixation of the centrifuged aspirate, and skill acquired by experience in interpreting the microscopic appearances have made it possible to make a correct diagnosis of cancer in some three-fifths to four-fifths of the cases in which it is present. False positive results are rare (under ½ per cent, according to Cooper and Papanicolaou, 1953), but it is, of course, most important to realize that negative results are of little value and must not lead to a sense of false security.

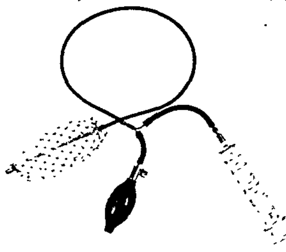


FIG 124 —"Abrasive balloon" used to increase cellular content of stomach

(*By courtesy of Cooper, Papanicolaou, and the Journal of the American Medical Association*)

Exploratory laparotomy

Exploratory laparotomy has become uncommon in these days of accurate [illegible] operative diagnosis. Edwards (1950), however, suggests that, in arriving at a diag[illegible] the history outweighs in significance all ancillary methods and advises that if the history is suggestive of cancer of the stomach, laparotomy should be enjoined [illegible] the fact that other investigations have yielded negative or equivocal results.

Mass radiography

Finally the mass radiography technique to discover unsuspected gastric [illegible] been investigated in the United States. St John, Swenson, and Harvey [illegible]

[illegible]

findings may be expressed in Table I.

This greater degree of selection does reveal a higher percentage of po[illegible] tions, but there are not many communities in which it would be practic[illegible] out such extensive examinations at regular intervals.

TABLE I

OBSERVATIONS IN A STUDY TO UNCOVER EARLY SILENT GASTRIC CANCERS
(JULY 1, 1945 TO APRIL 1, 1949)

	Number of patients	*Gastro-intestinal roentgen examinations*	*Findings*	
			Polyps	*Cancers*
Patients with achlorhydria	1,137	1,657	29 (plus 14 questionable)	6 (plus 1 questionable)
Patients with hypochlorhydria	313	343	9 (plus 6 questionable)	2
Patients with pernicious anaemia	94 (50 new, 44 previously examined)	187	4 (plus 1 questionable)	3
Relatives of patients with gastric cancer	81	78	—	—
Patients with haemoglobin levels of 11 g. or less	62	62	—	—
Patients with occult blood in faeces	87	63	—	—
	1,774	2,390	42 (2.9%)	11 (0.6%)

Summary

In summarizing it may be said that slight improvements in diagnosis have been made, and much thought has been devoted to the idea of making the medical practitioner "cancer conscious", all in an endeavour to bring the case to the surgeon at an earlier time. So far these efforts have not produced a measurable improvement. Abrahamson (1953), comparing a series of gastric cancers treated in 1919–1940 with a 1940–1950 series, found that there was no evidence that diagnosis was being made earlier. Boyce (1953) compared three series treated in 1933, 1941, and 1951, and also found that cases continue to come as late as ever. Some of this delay is due to the general practitioner, who often commences by treating the case symptomatically or as an innocent ulcer. The physician also is too ready to accept negative results of investigations without repetition or confirmation by other means; he may even invoke the aid of psychotherapy rather than press the examination of the stomach energetically.

Thus the improving results obtained in the treatment of gastric cancer are not due to earlier diagnosis. They are in the main due to the fact that improving methods of anaesthesia, the effect of chemotherapy and antibiotics in combating infection, modern methods of early blood replacement, and better understanding of post-operative treatment have had the following results.

(1) The operative mortality is less and some of the added number of survivors of resection become five-year survivors.

(2) The operability rate has increased. Patients who formerly were denied surgery because it was realized that the growth could not be extirpated by the abdominal route are now explored by the transthoracic route. Patients who were formerly considered too elderly or too feeble were denied operation, but now, with adequate support, they may survive resection.

(3) The resectability rate has increased. Tumours found in what were then inaccessible situations, or involving adjacent organs were often declared inoperable as their resection was attended with such a high mortality figure that resection might be considered unjustifiable. Survival is now common after upper gastric resection or after complicated or multiple resections, and many of these cases appear to have as long a survival period as those in whom the tumour is localized to the stomach.

GASTRIC RESECTION FOR CANCER OF THE STOMACH

Pre-operative management of the patient

This is much as was outlined in *British Surgical Practice*. Prophylactic chemotherapy, usually by a combination of penicillin and streptomycin, is recommended if the thoracic cage is to be opened, or if the patient is bronchitic. In other cases antibiotics are used if required to deal with any infection that arises.

Operative technique

There have been suggestions in some quarters that total gastrectomy should replace partial gastrectomy for gastric cancer entirely, in view of the wide lymphatic connexions in the stomach Meissner (1949) and some surgeons have followed this policy. There is still more support for radical *partial* gastrectomy, particularly when dealing with tumours of the pyloric end of the stomach. Thomas, Waugh, and Dockerty (1951) declare that a study of gastric tumours shows that the spread of cancer cells is never found more than 4 centimetres from the obvious tumour edge. They point out that Scott and Longmire, who carried out total gastrectomy for all gastric carcinomas, found only 18 per cent of their cases alive at the end of one year, a worse result than is usually obtained by partial resection. It has been found that the higher mortality of total gastrectomy and the greater disabilities which may follow it more than outweigh any likely benefits, indeed, no improved survival rates following its routine use have been produced. Troell (1953) described a series in which 90 per cent of the survivors of total gastrectomy had died within three years. Ransom (1953) made *post-mortem* examinations on 55 patients who had died following partial gastrectomy for carcinoma. Of the 55, no residual tumour could be found in 34 cases, 3 had residual tumour which could have been removable by total gastrectomy, and 13 had residual growth which would have been unaffected by total gastrectomy. Thus, although total resection would appear to give a possible 5 per cent improvement in long-term survival, such improvement would have been eliminated by the much higher operative mortality of total resection.

Total versus partial resection

The writer believes that the controversy on total versus partial resection has focused attention on the importance of transecting the stomach well above the upper visible and palpable edge of the tumour; a minimum of 4 centimetres, and preferaby 6 centimetres, should be allowed As the lesser curve of the stomach is only some 12–14 centimetres long, this means that, for growths involving the upper stomach, the upper transection must be through the oesophagus, and as about half of the localized gastric cancers involve the middle or upper part of the stomach, a high percentage of total and upper partial gastrectomies ("oesophago-gastrectomies") will be required. However, it is most important to emphasize that it is not necessary to do a total gastrectomy in order to remove the glands of the upper lesser curvature or even the paracardial group, as these can and should be stripped from the stomach. Such operations devascularize the stomach to some extent, and so a very high resection is necessary in all cases, even if the tumour is confined to the pyloric end. With regard to tumours near the pylorus, the danger of recurrence as a result of the intimate lymphatic connexions of the sub-pyloric and supra-pyloric glands with the glands round the hepatic artery and round the superior mesenteric artery, is greater than it is from invasion of the stomach stump at a high transection level.

It will now be convenient to consider points in the technique of gastric resection for growths at different levels.

Carcinoma of the pyloric end of the stomach

There has been no recent change in the technique of radical partial gastrectomy for

cancer affecting the pyloric end, though there is increased awareness of the need to transect well above the tumour and to strip the fatty and glandular tissues from the stomach up to the level of the oesophagus, previously described in *British Surgical Practice.*

The incision.—An abdominal approach is adequate for most cases of "lower partial gastrectomy" but at times, particularly in individuals with a deep chest, high diaphragm, or obesity, difficulty is experienced in clearing the glandular tissue from the cardia and in making a high anastomosis. In such cases there is a risk that operative difficulties may lead to inadequate surgery. Great help can be obtained by an upward extension of the incision over the lower sternum, and removing the xiphoid process, after carefully freeing it at the sides and posteriorly. The sterno-xiphoid junction may be cut through with a scalpel, although occasionally bone forceps are required. The anterior fibres of the diaphragm will be exposed and can be divided, when it will be found that a more direct approach to the cardia is obtained. This manoeuvre is particularly valuable if the xiphoid process is large and broad, but is of limited value in subjects with narrow costal margins.

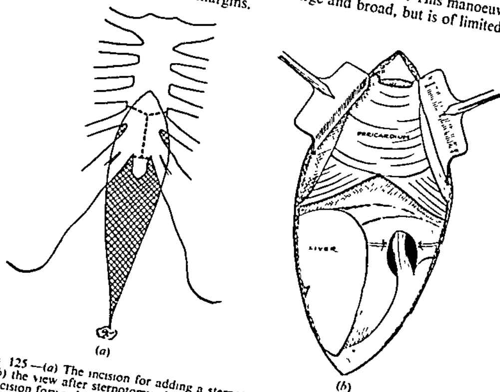


FIG 125.—(*a*) The incision for adding a sternotomy to an upper abdominal incision; (*b*) the view after sternotomy, downward reflection of the left lobe of the liver and incision forwards from the oesophageal hiatus

Sternotomy.—If the exposure is still inadequate then sternotomy is indicated. The anterior and posterior surfaces of the sternum are cleared as high as the 4th intercostal space and the inner end of each 4th space is also cleared anteriorly. With a Loebsche's or Keynes' sternotome the sternum is divided as high as the 4th space and the cut is then directed outward into the right and left 4th intercostal spaces (Fig. 125*a*) The two halves of the lower sternum can now be retracted laterally. Wangensteen, who has done much to popularize this approach, uses manual retraction with the aid of two assistants. A retractor may also be used, but some manual aid is helpful. The diaphragm can be divided up to the pericardium, but care should, of course, be taken to avoid opening the pericardial or the pleural cavities. Sternotomy gives all the advantages of a wide sternal angle, combined with a very high approach, but it is unsuitable if an appreciable length of oesophagus is to be removed. For the purpose

...that is, to improve the approach to the cardia in patients with a deep and

left triangular ligament of the liver and retracting the left lobe down and to the right also helps in these cases (Fig. 125*b*).

Closure of the wound.—Closure after this form of exposure presents no great difficulties and the convalescence is not altered, although some sternal discomfort may be present.

The diaphragm should be carefully re-sutured anteriorly and the suture line continued into the posterior rectus sheath and peritoneum, in order to prevent the possibility of subsequent herniation through the diaphragm. The sternum is repaired by drilling one or two holes in each side and wiring the two halves together. The fascia anterior to the sternum should be sutured together to give further stability. Dead spaces at the site of the removed xiphoid can be obliterated by suitable stitches between the inner parts of the rectus muscle or its anterior sheath, and the anterior edge of the diaphragm. If haemostasis is not perfect a small drain should be left in. The rest of the wound and skin are closed in the usual way.

The technique of resection of the lower and middle stomach is as decribed in *British Surgical Practice*. An addition to the standard procedure which may at times be of help, is resection of the right supra-pancreatic glands, that is, the glands which lie above the pancreas to the right of the left gastric vein and which are in intimate contact with the hepatic artery. If invasion of one or two of these glands has occurred or is considered likely to have occurred by spread from the subpyloric nodes or from the nodes round the left gastric artery, then the peritoneum of the posterior wall of the lesser sac can be divided and these glands dissected out, preferably in continuity with the other invaded nodes. Needless to add, care must be taken to avoid damage to the hepatic artery or pancreas.

Mid-gastric carcinoma

Tumours of the middle part of the stomach are as a rule so near to the cardia that in order to transect at a safe level above the growth, the upper line of transection may be across the oesophagus. For such cases an abdomino-thoracic incision is preferable. However, a tumour may be found to be unexpectedly high in the course of an operation in which an abdominal approach has been made. In some cases, for example, if a total or upper partial resection removing only 1–2 centimetres of oesophagus is required, an adequate resection is possible by adding a resection of the xiphoid process and perhaps a sternotomy. Further help may be obtained by incising the anterior margin of the oesophageal hiatus in the diaphragm, after under-running and dividing the branch of the inferior phrenic artery which passes in front of it. Care is necessary to avoid opening the pericardium. Such additions give only limited help and are unsuitable for more extensive oesophageal resections, except in cases of cardiospasm, where the gullet is elongated.

If it becomes evident that 3–4 centimetres of oesophagus must be excised after an abdominal approach has been made, there is no alternative but to do as much as possible by this approach, that is, transect and close the duodenum, dissect the stomach upwards, and prepare a Roux loop of jejunum. Then the abdominal incision should be closed and the patient is turned on to his right side and the operation completed through a thoracic incision.

Carcinoma of the upper stomach

In such cases, as with most tumours of the middle stomach, it is well to utilize an abdomino-thoracic approach from the first.

A difference of opinion exists on the subject of the advisability of carrying out

upper partial ("oesophago-gastrectomy") or total gastrectomy for certain cases of cancer of the upper stomach. The chief argument in favour of total resection is that cancer-laden lymphatics may be preserved in the pyloric remnant of the stomach. It is also difficult to remove the sub-pyloric glands adequately if the blood supply to the pyloric antrum is left intact. There is also a different line of argument. After oesophago-gastric anastomosis, the secretions and contents of the stomach remnant can flow freely into the oesophagus. It is found by Allison (1954) and others that this reflux may lead to a peptic oesophagitis with its complications of pain, bleeding, perforation, and, most of all, stenosis which is now well known to occur after simple oesophago-gastric anastomosis for stricture or cardiospasm. The writer's experience is that peptic oesophagitis is very unusual after upper gastric resection. Gastric carcinoma patients are notably free from stomal ulcer complications. The radical nature of the operation means that both vagus nerves are divided and most or all of the acid-pepsin secreting part of the stomach is removed. In operations for peptic oesophagitis, or for lower oesophageal cancer, where considerably more of the stomach is retained, the chance of peptic oesophagitis would undoubtedly be higher (Belsey, 1953). The writer has seen stenosis of an oesophago-gastric stoma on some six occasions. In two cases, recurrent growth was the cause of the trouble. In the other four, the anastomosis was done under difficult conditions and it is believed that the oesophageal mucosa was imperfectly sutured to the stomach. In three of these cases, dilatation of the stricture was possible and this led to prolonged relief. Such a degree of relief would not have been obtained if the stenosis were due to oesophagitis, for oesophagitis is often made more severe by stricture dilation since it leads to freer reflux into the oesophagus.

The argument that a total resection is a more radical means of extirpating the growth carries considerable weight. As the pylorus partially limits the spread of tumour, transection on its duodenal side usually ensures that one is past any extension of tumour from the body of the stomach. Allison (1954) very rightly points out that most gastric cancers are extensive and if a partial resection is done with one eye on getting the ends together all the time, it is too tempting to divide both oesophagus and stomach too close to the growth. On the other hand, certain growths are very localized to the cardia region and in such cases, transection at least 6 centimetres below the tumour will give reasonable assurance against recurrence in the stomach stump. Partial resection is a smaller operation and less of a strain on the patient. Furthermore, subsequent accidents are less likely to occur to the oesophagogastric anastomosis than to a mobilized jejunal loop (for example, obstruction or strangulation round the loop).

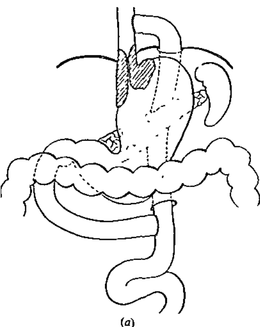
Partial resections and total resections with anastomosis of the gullet to a Roux loop give about equal comfort after operation.

There is little doubt that all the diffuse, most of the middle, and a high percentage of the upper gastric cancers will require a total gastrectomy. In a minority of the upper gastric cancers, the pyloric antrum and in some cases part of the greater curve side of the lower body of the stomach can be conserved. This remaining part of the stomach is, of course, deprived of its vagal nerve supply. As it is well known that the vagotomized stomach is slow to empty, it is as well to prevent the retention effects by a pyloroplasty, or more simply a pylorotomy, dividing the circular muscle of the pylorus down to the submucosa, as in the Ramstedt's operation (Tanner, 1951). If there is already a gastro-jejunostomy to the antrum it can be left intact, or if there is a coincident stenosed duodenal ulcer, a gastro-jejunostomy to the antrum may be made, and such cases are usually found to take meals with remarkable comfort.

Irremovable obstructed cancer of the upper stomach

Palliative oesophago-jejunal anastomosis.—It is sometimes found at operation that

a carcinoma of the stomach is irremovable, but is nevertheless causing such a degree of obstruction that an operation to short circuit the obstruction would give great relief. If the growth does not reach the cardia, then a short circuit between the jejunum and the greater curve of stomach above the tumour is usually satisfactory. If, however, the cardia or lower oesophagus are invaded then a short circuit between the oesophagus and jejunum is indicated (Fig. 126*a*).



(*a*)



(*b*)

Fi [illegible]

palliative oesophago-jejunostomy for obstructed irremovable carcinoma of the upper stomach

An abdomino-thoracic approach is necessary, though it is not necessary to divide more than the periphery of the diaphragm. It is nearly always impossible to bring an intact loop of jejunum up to the oesophagus above the growth without tension, and so the first stage must be the mobilization of a Roux loop of jejunum, long enough to enter the chest easily. It is desirable to bring the end of this loop into the thorax by a route which is short, and as far from the tumour as possible. If the loop is brought up through the lesser sac or anterior to the stomach, the jejunum may soon be invaded by growth from the stomach. Therefore the writer has evolved the following simple method. An incision is made under the left leaf of the transverse mesocolon, to the left of the inferior mesenteric vein and below the body of the pancreas. Through this opening, a finger burrows up behind the pancreas and behind the posterior peritoneum of the lesser sac and in front of the kidney and adrenal gland. After passing a very short distance, the posterior part of the diaphragm is met, and an opening about 5 centimetres long is made through it. This tunnel is widened sufficiently to draw the jejunal loop through it. An incision is now made in the mediastinal pleura and a short length of the lower oesophagus above the obstruc-

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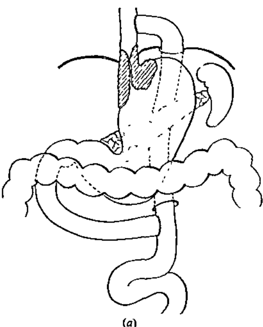
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Fi

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tion is mobilized. An anastomosis is made between the mobilized oesophagus and jejunum. The writer finds anastomosis of the end of the *jejunum to the side of the* gullet very satisfactory. Alternatively, the end of the jejunum can be closed and a lateral oesophago-jejunal anastomosis made. The *jejunal loop is fixed to the* diaphragm with a few interrupted stitches to relieve any tension on the anastomosis.

This short circuit acts by overflow from *the oesophagus but gives* complete relief of dysphagia (Fig. 126).

RESULTS OF TREATMENT

Harnett (1947) showed that, of 1,405 cases of gastric cancer treated between 1938 and 1939, *thirty-six who had had* a gastrectomy were still alive at the end of five years, a 2·5 per cent survival rate. In order to assess the present position it is necessary to make a present-day assessment of the five-year survival rate of all cases seen, but precisely similar statistics to those of Harnett are not now available. However, as mentioned previously, we should on present evidence be safe in anticipating an improved overall five-year survival rate, because of the diminished operative mortality rates combined with increased operability rates.

It is probable that the most notable achievements will be in the cases of upper gastric cancer. In 1938–1939, the vast majority of cases were considered inoperable, and if treated by gastrectomy, the mortality figure was nearly 100 per cent. Nowadays a high proportion of such cases are operable, and the mortality is between 9·5 per cent and 51 per cent in most clinics (Troell, 1953) In the writer's series of gastric carcinoma treated in the last two years, a radical Polya type of partial gastrectomy ("lower partial gastrectomy") was carried out in 42 per cent, a total gastrectomy in 32 per cent, and resection of the upper stomach and lower oesophagus ("upper partial gastrectomy") in 26 per cent of the cases. Fifteen years ago the last two groups, that is 58 per cent of the whole series, either would have been considered inoperable, or would have been inadequately resected.

Pack (1951) finds that 43 per cent of his gastric cancer cases require a total or upper gastric resection. In 1939, three out of a hundred of his cases lived five years (very comparable to Harnett's figure). In 1951, his most recent follow-up showed that, as a result of earlier diagnosis, increased operability and decreased operative mortality, *twelve out of a hundred lived for five years, a very notable improvement.* In the British Empire Cancer Campaign series reported by Harnett, there were no five-year survivors of patients suffering from cancer of the cardia region, and so it is interesting and encouraging to read that Sweet (1952) found that of his patients who survived resection of the cardia region, 17·5 per cent survived five years, the survival rate being similar for both adenocarcinoma and squamous-cell tumours of this region. Of thirty cases of adenocarcinoma of the cardia resected by the writer, nineteen survived operation and of these four (21 per cent) survived five years. This factor alone must increase the overall five-year survival rates of gastric cancer.

Allison (1954) has carried out seventy-five radical total gastrectomies for primary carcinoma of the stomach, a high percentage of the cases being extremely advanced. Of these, twenty-two died of their operation within three months, seventeen died of recurrence within one year, seventeen more died of recurrence between one and seven years of operation, and nineteen are still alive, of whom five were operated on over five years ago. Of twenty-three resections for adenocarcinoma of the cardia region with oesophago-gastric anastomosis, ten died of their operation, and thirteen survived. Of the thirteen survivors, four died in under one year, three in one to two years, three died after three years and three between five and six years. Four are still alive, two for over six years. Allison is not now in favour of the latter type of operation because of the incidence of post-operative dyspepsia and oesophagitis (one patient

died of perforation of an oesophageal ulcer into the pericardium four years after operation).

The way in which a greater number of survivors of resection is now available for long-term survival was well shown by State *et al.* (1947) who, in reporting 586 cases of gastric carcinoma treated between 1936 and 1945 inclusive, compared their figures of 1936 and 1945 as follows.

	1936	1945
Operability ...	57%	88%
Resectability ..	28%	80%
Operative mortality .	25%	4 9%

In 1936, out of a hundred cases, about twelve would have survived gastrectomy, in 1945, no less than sixty-six. Even if the five-year survival rate of those patients who successfully undergo resection drops because more extensive cases are dealt with, one could confidently predict a higher overall five-year survival rate. In actual fact, resection of all or part of a neighbouring organ does not appear to affect the five-year survival rate adversely (McNeer and James, 1948). Jemerin and Colp (1952) also report that, despite an increasing resectability rate for gastric cancer, the five-year survival rate is improving.

(*See also British Surgical Practice* Stomach—Diseases of, Vol. 8, page 49, S Key 312.)

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SURGERY IN KOREA

By A. G. HARSANT, C.B., O.B.E., Q.H.S., M.D., M.S., F.R.C.S.
DIRECTOR OF SURGERY AND CONSULTANT SURGEON TO THE ARMY

Active hostilities in Korea lasted for 3 years—from the summer of 1950 to the summer of 1953. The forces of the United Nations were contributed to by 21 nations, the large majority being supplied by the United States of America.

The contributions from the United Kingdom and the British Commonwealth were, by 1951, formed into one Commonwealth division, itself forming part of the 1st Corps of the 8th Army in Korea. This division was composed of troops from the United Kingdom, Australia, Canada, New Zealand and India, with an attached squadron of the South African Air Force.

GENERAL MEDICAL ARRANGEMENTS

The field medical units in the Commonwealth Division in Korea included three Field Ambulances (United Kingdom, Canadian and Indian), and one Field Dressing Station (Canadian). In addition there was one 1,000-bed General Hospital in Japan. This Commonwealth Hospital was formed by the amalgamation of a 600-bed General Hospital from the United Kingdom, with a previously existing Australian hospital, with the addition of an element from Canada.

There were no Commonwealth medical or surgical units in Corps or Army establishment, the forward surgery being carried out at American Mobile Army Surgical Hospitals (including one staffed throughout by Norwegian surgeons and staff). Commonwealth casualties were transferred thence, either direct to the Commonwealth Hospital in Japan, or after further treatment in American Evacuation Hospitals in Korea and General Hospitals in Japan.

GENERAL PRINCIPLES OF WAR SURGERY

The general principles as developed during the two world wars, and as enunciated in the *Field Surgical Pocket Book* (1950), in *The History of the Second World War* (1953), and in the article by Rob (1947) were again found to be sound.

Where conditions of the campaign did not allow these principles to be fully carried out (as in periods of sudden advances and retreats in the early months of the war) the same complications recurred, and the low morbidity rates were not maintained.

On the other hand, the favourable circumstances obtaining in the last year of the campaign (when conditions were largely static and when the United Nations Forces had complete air superiority, and when helicopter and winged aircraft for medical evacuation were in lavish supply) are unlikely to be repeated in any future large-scale international conflict. It will be unwise to depart from these well-tried principles, at any rate in the early months, of a future war.

The practice carried out by the Americans closely parallels that of the forces of the United Kingdom except in details. It is still recommended by them that all amputations carried out in forward surgical units shall be of the circular guillotine type, without any attempt at formation of flaps. This amputation is followed by the immediate application of adhesive strapping extension, which has to be retained until the skin

is pulled down over the end of the stump. It is held that all amputations done under field conditions must later be re-amputated at a site of election, which is better carried out at a later date in base or home hospital. Secondly, the "Tobruk Splint"—of proved worth for the transport of injuries and wounds of the thigh—has not been accepted by the Americans, who prefer to transport such casualties in a plaster of paris spica.

RESUSCITATION

Whole blood

Blood was in ample and generous supply throughout the campaign. Practically all the blood used for resuscitation in Korea was from United States sources. The blood was collected in the United States, flown over to the Medical Depot in Tokyo, and thence distributed to all units in Korea by air. Blood used in the Commonwealth Hospital in Japan was collected from local Commonwealth sources by an attached Field Transfusion Team; similar arrangements were available for the other hospitals in Japan. The blood received by casualties in the forward areas was at least 8 days old and in many cases much older Although undesirable, little practical disadvantage appears to have resulted from this under the conditions of this campaign.

The effect of storage and transport of blood under these conditions was studied by research teams in Korea and in Tokyo. It appears that the degree of disturbance and jolting of the bottles in crates, when transported this distance by air has little effect on the condition of the blood—deterioration being more closely related to the length of storage. The longer blood is stored, the more potassium ions are mobilized into the serum. Consequently, a very large transfusion with blood which has been stored for many days, may result in the danger of potassium toxaemia.

Intra-arterial transfusion.—This procedure was used on occasion for severe and catastrophic loss of blood, and although it was found to be life saving it has not been without its complications—gangrene of the hand having been reported following transfusion into the radial artery of an undamaged arm.

Plasma

Plasma was plentiful in American units in the early months of the campaign, but a considerable incidence of jaundice was reported in casualties from Korea, after they had reached base hospitals in the United States. This was in spite of the fact that the plasma used had been previously irradiated Consequently, in 1952, plasma was almost completely replaced by plasma expanders such as dextran.

ANTIBIOTICS

Parenteral penicillin was commenced at the most forward medical units, with the addition of streptomycin for abdominal wounds. Aureomycin, and terramycin were available, but were usually reserved for special cases, or for those with infections insensitive to penicillin. The local use of antibiotics was little practised

FROST-BITE

Prevention

The winter in Korea is a very severe one. During the first winter of the campaign, when full winter clothing was not available to all troops, and more particularly when there were rapid advances and retreats in wet and very cold weather, frost-bite casualties were not uncommon.

It was again evident that many of such cases should be preventable, provided that the general nutrition of the troops is good, that winter clothing is adequate, and that

the men themselves are *trained* and are able to carry out a few simple precautions.

Treatment

The types of case treated at the Commonwealth Hospital have been described by Watts (1952), and the results of treatment in a group of frost-bite cases at a hospital in the United States, by Canty and Sharf (1953).

No difference was noted, whether treatment had been carried out in an atmosphere conducive to rapid thawing, or in one of prolonged cooling. The time of exposure, and the preliminary treatment, did not appear to have made much difference in the final state of the limb.

Cases initially treated with paravertebral blocks, subsequently required higher levels of amputation, than the remainder of cases not so treated. Cortisone was tried in a few cases, but did not influence the course of the condition. Routine early intravenous injections of Novocain and heparin, and of vasodilators, did not give any apparent benefit

The best results were found to follow conservative treatment, reserving active surgery until the maximum of tissue had recovered, and a line of demarcation formed. A minimal amputation was then performed, or dead tissue was removed, followed by immediate skin-grafting.

CASUALTY EVACUATION BY HELICOPTER

This most attractive method of casualty evacuation has been in use in more than one theatre of hostilities during the past few years. There are very definite limitations in the use of the helicopter imposed by terrain and climate, and by the relative air [illegible] against the terrorists in Malaya, [illegible] Casualties occur mostly in [illegible] in be picked up by the aircraft, the casualty has to be transported by hand carriage to an open space, often a mile or so away, or to a sufficient clearing made by felling trees. Identification of the site by a helicopter pilot is difficult, and usually has to be preceded by a reconnaissance by a light aircraft The wind currents in hot steamy hilly country such as this, may make the procedure very hazardous.

Helicopters do not at present fly at night, or in mist or fog; they have a limited radius of flight, and their use requires a fair degree of air superiority.

In the Korean theatre of hostilities, on the other hand, conditions were very much more favourable. Over the last year, when conditions were static, there was almost complete Allied air superiority and in these conditions helicopters could be operated from air strips close up behind the front line. Suitable landing grounds were made available, or were fashioned at almost all forward surgical units, and the helicopter was free to evacuate patients to surgical units laterally, or to the rear.

Under these conditions, helicopter evacuation was liberally used. Specialist surgical units (for example, neurosurgical and vascular) could be sited well forward and yet receive cases from a very wide front In quiet periods, it has been the custom to evacuate all severe battle casualties to the forward surgical hospitals, or to the specialist units, by helicopter direct from, or from close behind, the battalion or regimental aid posts.

With this rapid evacuation, some unusual problems have been posed. Cases with such severe or multiple injuries as would previously have been unlikely to have reached the surgeon may now arrive at the operating tent within 1 hour of being wounded. Moreover, the usual custom of giving hot sweet tea or other drink to casualties as soon as they reach the regimental aid post, has had to be modified, otherwise the patient may arrive on the operating table before the fluid has left his

stomach. The very efficient insulated Casualty Evacuation Bag into which the patient is placed, as in a sleeping bag, has permitted helicopter evacuation to be carried out even at sub-zero temperatures.

It is, however, most unlikely that such favourable conditions for the use of casualty evacuation by helicopter will be repeated in any future large-scale international conflict, at least until the initial air inferiority or parity has been overcome.

BODY ARMOUR

This has been developed and has been in limited use for some time by troops of the United States.

Made of a padded nylon material, or of overlapping plates, in the form of a waistcoat or vest, it has been shown to have definite protective value, preventing wounds of the covered parts by smaller metal fragments. A similar garment is being developed to cover the lower torso (*Military Surgeon*, 1953). There are, of course, disadvantages of extra weight and clumsiness for the infantry soldier and there must come a point at which such disadvantages outbalance the extra degree of protection afforded the wearer.

VASCULAR SURGERY

Increased importance has been placed on the early recognition of wounds of the major and minor arteries. Such increased awareness, together with the readily available helicopter evacuation, has enabled these cases to be concentrated on a forward mobile surgical hospital. Reports of cases treated in this centre have been given by Cooke and his colleagues (1953), and by Jahnke and Seeley (1953).

Of 77 cases of acute vascular injury treated in one 4-month period, 43 cases were of lesser-sized arteries (brachial, profunda femoris, radial, ulnar, anterior and posterior tibial) and were treated by simple ligation. Amputations were later necessary in 5 (11·5 per cent) of these.

The remaining 34 cases were of major vessel injury (carotid, axillary, brachial, iliac, femoral, or popliteal) which were treated by direct end-to-end suture (after excision of about 1 centimetre of the damaged ends), or by autogenous vein grafting. Amputation was required later in 3 of this group (8 8 per cent).

The time lag between injury and surgical repair averaged 9 hours, but successful repair was achieved in 77 per cent of cases treated up to 15 hours after wounding. The average time taken over the actual repair varied from 15 to 45 minutes, according to whether end-to-end suture or grafting was carried out.

It was found that the previous use of a tourniquet may determine eventual failure, presumably by damage to collaterals, but it is encouraging to say that no case was seen in which it was impossible or impracticable to afford repair and give coverage to the damaged artery.

NEUROSURGERY

With the aid of helicopter evacuation, it has been possible to develop an advanced neurosurgical centre by attaching a mobile neurosurgical team to one of the very advanced mobile surgical hospitals. Direct evacuation of casualties with cranial and spinal injuries from the Battalion Aid Stations by helicopter, right up to this unit has enabled this team to operate on all such cases as a routine and with an injury-to-operation delay of only a few hours.

Following full surgery at the advanced mobile surgical hospitals the cases were then evacuated by air direct to the main neurosurgical centre in Tokyo (by helicopter from the advanced neurosurgical unit to the nearest air strip, thence by large casualty

evacuation aircraft to Tokyo without having to pass through intermediate medical units.

Brain injury

Patients with penetrating brain wounds were found to be fit for travel 3–4 days after the operation, but those with transventricular wounds are better held for a few more days.

Meirowsky and Barnett (1953) have recorded their experiences in charge of this unit, insisting on the necessity for fully trained nursing staff to be available. Cases with cranio-cerebral trauma often depend for their survival in the post-operative period on adequate skilled nursing and the nurse–patient ratio must be high.

Under the conditions of the later years of the campaign, the incidence of meningo-cerebral infection (as high as 41 per cent during the early phases of the war, when definite treatment of cranio-cerebral wounds was not undertaken till the cases reached Tokyo) was reduced to less than 1 per cent.

Spinal injuries

All wounds of the spine were operated on immediately, with laminectomy whenever indicated. These cases were subsequently nursed with tidal drainage of the bladder through an indwelling catheter. The patients were turned every 2 hours, day and night, from back to face, with the aid of padded stretchers, and later, on a Stryker turning frame. By these methods, decubitus ulcers were entirely avoided.

Although Stryker turning frames are too heavy and bulky for inclusion in the equipment of a mobile team, they have proved of immense benefit in the nursing of paraplegics. The patient, once lain on one of these frame beds, can remain on it throughout subsequent evacuation, and the labour entailed in continuing the 2-hourly turning is small. The frames have also been extremely useful in the treatment of cases with extensive or circumferential burns.

In the absence of chest or abdominal complications, patients with spinal wounds were ready for evacuation to Tokyo within 3–4 days after laminectomy.

CHEST WOUNDS

Management of cases of chest injury has followed that in use at the end of World War II. King and Harris (1953) have described the results of 405 major thoracic wounds received at a large hospital in Japan, from 5 hours to 3 days after wounding. They stress the importance of early, repeated, and efficient aspiration of haemothorax. They found that decortication was rarely required if aspiration had been early and persistent. The only cases of clotted haemothorax and unexpanded lung (10 in all) resulted from inadequate or mismanaged early treatment. Closed drainage, with under-water seal, was not good as it led to loculation and infection, besides being more difficult to maintain during transport.

RENAL INSUFFICIENCY

A special centre was maintained at a forward evacuation hospital—staffed by members of a research unit—to which were evacuated by helicopter all cases of acute renal [illegible] haemorrhagic [illegible] of potassium, sodium and alkali reserve, and for haemodialysis.

If the patient did not respond to a programme of fluid and protein restriction and the use of selective cation-exchange resins, and if there was evidence of potassium

intoxication, haemodialysis was then commenced, using a "Merril" type of artificial kidney.

This renal insufficiency unit is expensive in the use of skilled scientific personnel, and depends for its value on a situation permitting a forward position of the unit, and on readily available air evacuation to the unit from all forward surgical installations. There was, however, in the instance cited, a definite salvage rate of 30–50 per cent of those cases requiring the use of the artificial kidney. Some cases recovered after further treatments with the artificial kidney.

(*See also British Surgical Practice* Gunshot Wounds and Allied Injuries Vol 4, page 352)

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ADRENAL GLANDS

See also B.S P., Vol. 1, p 94, S. Key 12.

Total bilateral adrenalectomy

Glycyrrhizin

Use with cortisone.—HUDSON and his colleagues (1953) have investigated the use of glycyrrhizin in total bilateral adrenalectomy, following its reported success in Addison's disease (Groen, 1952). [illegible] influenced phe[illegible] menopausal, w[illegible] and one castrated male with prostatic carcinoma, were selected [illegible] on 25 milligra[illegible] cortisone was [illegible] collected 24-hourly. In Case 1 (metastatic breast adenocarcinoma) [illegible] 17-ketosteroid excretion was 1·99 milligran[illegible] yielded a concomitant rise in the 17-ketoster[illegible] In Case 2 (metastatic prostatic adenocarci[illegible] the mean level of 17-ketosteroids was 2 m[illegible] Gradual diminution of cortisone produced [illegible] while complete withdrawal and reliance on glycyrrhizin produced levels too low for determination In Case 3 (breast adenocarcinoma) 50 milligrams cortisone daily, yielded a mean 17-ketosteroid level of 3 5 milligrams Reduction to half the cortisone produced a daily excretion of 2·5 mi[illegible] cortisone reduced [illegible] Addison's disease [illegible] patients were stero[illegible] metadinitrobenzene [illegible]

Hudson, P B, Mittelman, A, and Mann, P. (1953). *J. clin. Endocrin.* 13, 1064.

AFTER-CARE—POST-OPERATIVE

See also B.S P, Vol 1, p 130, S. Key 17.

Water retention

Causative factors

Study of cases.—LE QUESNE (1954) has continued his study of post-operative water retention With Lewis (1953) he showed that the post-operative disturbance of salt and water metabolism consisted of primary water retention, early and late sodium retention. Their method of examining 24-hour pooled urine specimens did not, however, establish the duration of primary water retention, and 5 cases were therefore selected for further study. Two were excision of the rectosigmoid, 2 Wertheim's hysterectomy, and 1 a sub-total hysterectomy with left inguinal colostomy In all cases, the intake of water and electrolytes was oral [illegible]

[illegible] the present cases the post-operative urinary changes were identical with those produced by injection of anti-diuretic hormone In Case 5, prolonged primary retention produced mild water intoxication, with extra-cellular hypotonicity Such cases have been reported. Zimmer-[illegible]

The relation of this condition to the post-operative administration of fluids is important, implying that, when fluids are being given intravenously, the volume of 5 per cent glucose should be controlled as carefully as that of isotonic saline

Le Quesne, L. P. (1954). *Lancet*, 1, 172.

AMPUTATIONS

See also B.S.P., Vol. 1, p. 178, S. Key 24

Arteriosclerosis

[illegible]

double amputations, so that there were 90 amputations in the series Seven amputations were below knee and in the remainder above-knee amputations were performed. In analysing the cases the authors have classified the responsibility for the loss of the leg as one of three types. spontaneous evolution of the arteriosclerosis which it was not possible to control, injury, accidental or inflicted by the patient, or resulting from neglect by the patient; and faulty medical management. They find that in two-thirds of the cases the responsibility for

[illegible]

after amputation, since the incidence of later amputations is as high as 40 per cent. It is preferable to perform the sympathectomy before the patient leaves hospital after having had an amputation. The authors finally emphasize that the doctor must remain alert to the signs of complications that cause gangrene and treat them more vigorously when they occur

Hemipelvectomy

Indications, technique and results

[illegible]

bone infections refractory to other forms of therapy The best results have been achieved in cases of massive primary or recurrent osteochondroma and chondrosarcoma The most important pre-operative measure is psychological preparation of the patient for a mutilating operation, sulphonamides and penicillin have been used for bowel preparation in the present series. The safest method of anaesthesia is, probably, nitrous oxide, oxygen and ether inhalation, with Pentothal induction, hypotensive anaesthesia was used in the last 3 cases of the series, with dramatic reductions in bleeding The technique used was that of Sir

[illegible]

Edwards, E. A , McAdams, A J., and Crane, C. (1953). *New Engl J. Med.*, 249, 514.
Taylor, G W , and Rogers, W. P., jun. (1953). *New Engl. J. Med*, 249, 963.

ANAESTHESIA—GENERAL, LOCAL, REGIONAL AND SPINAL

See also B S P., Vol. 1, p. 25, S. Key 26.

Controlled hypotension

Intracranial operations

Hexamethonium: indications and contra-indications.—Controlled hypotension at intracranial operations is discussed by Wiklund (1953). Hexamethonium has been used for this purpose, during a period of 1 year, in over 70 cases. The series demonstrated 3 main indications for controlled hypotension: (1) *arterial aneurysms;* (2) *highly vascular tumours* and malformations; and (3) intracranial rise of pressure and cerebral oedema The contra-indications include, grave cardiac and renal changes, pulmonary and extra-pulmonary processes that considerably impair the oxygen uptake, and shock or impending shock; the

administered were: in 16 cases, 20 milligrams or less; in 26 cases, 20–50 milligrams; and in

inadvisable in intracranial operations; if necessary, intra-arterial transfusion of blood should be given under positive pressure

Effects on blood-sugar

Diabetic and non-diabetic patients

The effects of general anaesthesia and hexamethonium, on the ... *en investigated by* ... itients, prepared for ... of control, and the proposed anaesthetic agent, only 2 cases gave rise to any anxiety. In these cases, severe hypoglycaemia occurred towards the end of the operation, during which the technique of controlled hypotension with hexamethonium bromide was used As these cases suggested that hexamethonium might potentiate the action of parenteral insulin, a series of experiments was designed A *selection was made of patients aged 20–50 years,* with a fasting blood-sugar ... who had been on a normal full

Hexamethonium, when used, was given just after the 5-minute post-induction ... the operation was begun just before the 10-minute post-induction sample. The results, in ... *follows.* (1) *during superficial operations in 20 subjects,* ... (2) upper abdominal section in 10 subjects produced ... which was not clinically important; (3) the blood-sugar ... hexamethonium given to 25 patients

Griffiths, J. A. (1953) *Quart. J. Med.*, 22, 405.
Wiklund, P. E. (1953). *J. Neurosurg.*, 10, 617.

ANGINA PECTORIS

See also B.S.P., Vol. 1, p. 254, S. Key 30.

Resection of afferent pathway

Results of operation

EVANS and POPPEN (1953) have performed resection of various parts of the sympathetic anginal pathway (*the first to the fourth thoracic ganglion on the right and left*), for the relief of anginal pain, in 16 patients. The series comprised 10 females and 6 males, whose

factory in 4 The higher the resection the better were the results, especially on the left side. Throat or jaw pain was not a constant residual finding, relief of even this unblocked pain may be the result of decreased strain on the heart in hypertensive cases, and increased exercise tolerance or actual dilatation of the coronary bed The relief of status anginosus

The operation

view of the

urs becomes

lromes, with

marked psychic overlay, have been unsatisfactory It is believed that the results will always be more satisfactory in hypertensive patients

Evans, J. A , and Poppen, J L (1953). *New Engl J Med.*, 249, 791.

APPENDIX—TUMOURS OF

See also B S P., Vol. 1, p 320, S. Key 278.

Adenocarcinoma of the appendix

Symptoms and signs

NARDELL (1953) describes 5 cases of adenocarcinoma of the appendix. The first patient was a woman aged 43 years, with pain, tenderness and rigidity in the right iliac fossa

appendices removed at operation.

Nardell, S G. (1953). *Brit. J Surg.*, 41, 136.

ARTERIES

See also B S.P., Vol 1, p. 327, S. Key 37.

Spontaneous thrombosis

Right carotid artery

Diagnosis.—A case of spontaneous thrombosis of the right internal carotid artery, diagnosed by angiography, is reported by SVIEN and KARAVITIS (1954) A white male patient, aged 43 years, was admitted to hospital with a history of having experienced sudden onset of

severe bifrontal headache 1 week prior to admission. Transient diplopia had occurred 4 days prior to admission, sudden onset of inability to move the left leg, with weakness in the left arm, without loss of consciousness, dizziness or defect of speech, had developed suddenly 24 hours before admission.

artery, as the tip of the needle might have projected up into the external carotid artery rather than into the common carotid artery. After a second injection, with the x-ray beam directed over the neck rather than the head, dye again filled the external carotid artery but only

n carotid artery down-

was so near the bifur-

Abdominal aortic aneurysms

Treatment

After spinal anaesthesia laparotomy was performed The aneurysmal mass was found to extend downwards from the region of the left renal vein to the bifurcation of the aorta. A band of cellophane was passed round the aorta, drawn tight at a point proximal to the

less severe Death took place suddenly after rupture of the aneurysm.

Excision and grafting.—The treatment of abdominal aortic aneurysms by excision and grafting is discussed by HELDEN, KIRKLIN and GIFFORD (1953) The majority of such aneurysms are arteriosclerotic, occurring in males in the later decades of life. The most

The poor prognosis

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rysm by reinforcing

The authors report

below the origin of

logous aortic graft, the

hape of the grafts used.

cases. The operation cannot be used for

nal arteries The risk of ischaemia from

be prohibitive

Arterial aneurysms

Aetiology symptoms and treatment

Arterial aneurysms are discussed by ROB (1954). The 6 main aetiological factors are: (1) Congenital abnormalities; (2) trauma; (3) arteriosclerosis, (4) syphilis; (5) mycotic aneurysms in patients with bacterial endocarditis; and (6) polyarteritis nodosa and allied

diseases. Clinical features vary with the site of the aneurysm. The majority of abdominal aneurysms cause pain, frequently in the back but often radiating to the umbilicus; the patient may find the lump and may even notice pulsation Other symptoms consist, in general, of pressure effects upon the nearby nerves and veins, aneurysms near a joint may cause

particular reference to the prognosis of the arteriosclerosis Accurate pre-operative knowledge of the anatomical position of the aneurysm can be obtained clinically, but an arteriogram is essential in many cases. Complications of aneurysm include: rupture, often preceded by a period of leakage; thrombosis, peripheral emboli, enlargement with pressure on nearby structures; and dissection Treatment is not indicated unless the aneurysm is causing symptoms or threatening the patient's life, the untreated prognosis of an aneurysm depends particularly on its cause and location The first essential is to treat the cause, this being usually a prelude to treating the aneurysm itself There is no effective medical therapy.

of aortic aneurysms

Ischaemic lower limb

Arterial grafting

Technique.—Arterial grafting for the ischaemic lower limb is discussed by EASTCOTT (1953). Reconstructive arterial surgery may be said to have begun in 1897 In 1902, a technique was evolved for performing vascular anastomoses, and, in 1908, these principles were applied to free vessel transplants in experimental animals. The outlook improved with the introduction of heparin in vascular surgery At present, no manufactured product can equal a blood vessel as a graft for peripheral arteries The ideal composition is that of the host's own tissues; all altered homografts give worse results than when used fresh The artery bank should provide sterile, safe grafts, which can be stored indefinitely, the grafts should be transportable Glycerol, which protects cells during freezing, is now incorporated in the storage method used by the author Arteries for grafting should be removed, if possible, within 6 hours after death, young subjects are preferable, infective conditions, naturally, preclude the taking of grafts The lengths of artery can be kept in ice-cold sterile Ringer's solution, for several hours if necessary, before freezing The frozen artery bank used by the

immediate failures, 3 of these showed little change in symptoms; in none of these patients could the peripheral pulses in the affected limb be felt, post-operative arteriography showed little change in the extent of the occlusion, amputation was required for the fourth patient, in whom grafting had been performed for spreading gangrene Nine grafts were functioning when the patients left hospital, and these grafts have remained patent. The pulse returned to the foot on the affected side and remained palpable arteriography, 14 or more days post-operatively, showed the graft to be fully patent; symptoms were completely relieved.

Aortic grafts

Characteristics of fresh and freeze-dried specimens

PATE and SAWYER (1953) describe some elastic characteristics of fresh and freeze-dried

practice Replacement of the femoral head by a plastic prosthesis has shown gratifying short-term results, and it is anticipated that this principle may be applicable to conditions unsuitable for mould arthroplasty. The timing of the operation depends on patient and surgeon, antibiotic therapy appears to have obviated the need for delay after apparent quiescence of infection Preparation for operation includes blood transfusion prior to induction of anaesthesia; recent skiagrams should be available in the theatre The use of a prosthesis has raised the standards of end results, the surgeons can anticipate the prognosis of arthroplasty with reasonable accuracy in all except the knee joint Success has followed the interposition of fascia or other material in certain joints; separation of the shaped ends of the bones by splinting or traction followed by physiotherapy, however, seems to be of greater importance.

Technique and results of operation.—Arthroplasty of the knee has offered many problems in chronic arthritis, particularly because fascia lata inserts wear away in weight-bearing joints Taking advantage of the lack of tissue reaction to nylon, KUHNS and his colleagues (1953) have used nylon membrane as a separating material, and have studied the results in 70 cases. The indications for the operation include bilateral knee ankylosis, joints with intractable pain, and osteoarthritic knees in which prolonged conservative treatment has failed Using a parapatellar incision, the capsule is incised and the bones separated. The cruciate ligaments and semilunar cartilages are then removed. The tibial plateau is grooved, and the femur shaped to fit on to the new surface The patella is thinned down to a coin-shaped disc Remaining projections are smoothed with a rasp, and the fit of the joint surfaces is tested. The nylon membrane is attached to the femur by stainless steel staples driven into the bone, covering both condyles and the supracondylar region. Post-operatively, the joint is immobilized for 5 days, and gradual rehabilitation is thereafter employed Weight-bearing in plaster is allowed after 3 weeks Good function was usually obtained after 6 months, although improvement continued in some cases for up to 2 years Immediate post-operative complications were fairly common, but persisted in only 10 of the cases Discussing the end results, the authors have defined as satisfactory those knees with 60 or more degrees of painless active flexion in a stable joint Of the 70 cases, 58 were satisfactory, the shortest period of observation being 6 months

Buxton, St J D (1954) *Ann R Coll Surg Engl.*, 14, 1
Kuhns, J. G., Potter, T A., Hormell, R. S , and Elliston, W A. (1953) *J Bone Jt. Surg.*, 35A, 929.

BLADDER—INFECTIONS

See also B S P , Vol. 2, p. 103, S Key 54

Abacterial cystitis

Symptoms and treatment

HORNE (1953) describes a series of 11 cases of abacterial cystitis, a condition which may last for months or even years, and which has been described more often in recent times. The onset is acute and usually severe with dysuria, frequency and urgency Haematuria is not uncommon and is usually terminal The urine is loaded with pus, but no organisms are

the organ is irritable. Nephrectomies reported elsewhere and carried out on a mistaken diagnosis did not show any disease of the renal cortex though the mucous membrane of the

and a condition present for years may clear up in a day or so. The writer found that marpharside in some cases was less ... results with streptomycin were as good as those ex... possible septic foci were examined, the writer says ... or tonsillar sepsis and the syndrome is not easily established. It is difficult to determine the significance of sexual intercourse in this disorder though in the male it seems to have been a frequent precursor. Reiter's syndrome may be preceded by or associated with abacterial cystitis and though pleuro-

Horne, G. O. (1953). *Brit. J Urol.*, **25**, 195.

BLADDER—TUMOURS

See also B.S P., Vol 2, p 140, S. Key 58.

Primary bladder tumours

Primary sarcoma

... Primary sarcoma occurs in less than 1 per cent of ... ases have been myosar- ... leiomyosarcomata, and ... with menorrhagia and haematuria. A hysterectomy was performed for fibroids, and she was found to have a ... A biopsy showed it to be ... on and deep x-ray therapy was ... rapubic incision, and deep x-ray ... haematuria recurred. Cystoscopy ... the superior bladder wall. Local

to have a 2-centimetre tumour in the dome of the bladder, and partial resection was per... found to have ... circumscribed ... idly developed ... ust, 1951. The

Ramey, P. W, Ashburn, L. L, Grabstald, H., and Haines, J. S. (1953) *J. Urol*, 70, 906.

BLOOD-PRESSURE—HIGH AND LOW

See also B.S.P., Vol 2, p. 189, S. Key 61

Hypertension

per 100 cubic centimetres; (2) convalescence from a stroke or coronary occlusion for less than 6 months; (3) age above 55 years, and (4) inability of the patient to co-operate in a careful post-operative programme because of intellectual deficiency or emotional instability The operation performed on 70 of the patients was Adson sympathectomy, plus either subtotal or total adrenalectomy In cases of subtotal adrenalectomy, all adrenal tissue was removed except a piece about 6 millimetres in diameter adjacent to the adrenal vein on the left side The operations were performed through a retroperitoneal incision and in 2 stages about 10 days apart. These cases were followed for 1–37 months post-operatively The results showed that the response had been excellent in 23 per cent, fair in 23 per cent, and poor in 30 per cent, 24 per cent died Only 1 patient died from uncomplicated adrenal insufficiency, deaths were usually due to stroke or coronary occlusion Improvement was greatest in cases with paroxysmal dyspnoea or congestive heart failure pre-operatively Cases subjected to subtotal adrenalectomy usually required adrenal cortical replacement therapy post-operatively

Jeffers, W A, Zintel, H A, Hafkenschiel, J H, Hills, A G, Sellers, A M., and Wolferth, C C (1953) *J Amer med Ass*, **153**, 1502.

BONES—DYSTROPHIES

See also B S P., Vol **2**, p 279, S Key 68.

Leontiasis ossia

Clinical picture

Pygott and Scott (1953) review the literature on leontiasis ossia and present details of a case. They point out that leontiasis ossia is not a pathological entity, but a clinical picture, and any condition capable of causing slowly progressive facial and cranial deformity may be included The authors, however, restrict attention to leontiasis ossia in the sense in which the term was first used by Virchow to describe a chronic progressive sclerosing periostitis of the facial bones and skull The case on which they report is that of a man of 53 years with hyperostosis of the skull, thoracic spine, ribs, sacrum, and left tibia Radiological examination of the skull showed dense masses of ivory bone obliterating all the sinuses The bones of the base of the skull and the facial area were enormously thickened The left mastoid was dense and no
mass arose fr
the thoracic

opinion of the authors that leontiasis ossia is a rare but significant entity of its own, unrelated to other causes producing similar external deformities Though it generally affects the cranium alone, general extension to other parts of the skeleton can occur

Pathology

murmur Radiological investigation showed the presence of megalo-ureters and a large lobulated bladder A plastic operation was performed on the ureters in order to facilitate drainage One year later treatment was required for slipped femoral epiphyses, a rachitic rosary and enlargement of the wrists and interphalangeal joints The patient was given a protein-poor diet, aluminium hydroxide, calcium lactate, vitamin D, sodium chloride and a molar citric acid-sodium citrate mixture. This treatment was of value in controlling acidosis Bilateral gynaecomastia developed at the age of 16 years. Retardation of general growth was attributed to renal disease and aortic coarctation Subsequently various skeletal changes

associated with hyperparathyroidism, and the findings included gross thickening of the calvarium, maxilla and mandible and obliteration of the air sinuses and air passages. The

pituitary, thyroid and adrenal glands were enlarged. Among the pathological findings were hypoplastic kidneys, granulosa cell tumour of the testis, massive left ventricular hypertrophy aortic coarctation and calcification of the peripheral arteries.

Cohen, J., and Diamond, I. (1953). *Arch. Path.*, 56, 488.
Pygott, F., and Scott, M. G. (1953) *Brit. J. Radiol.*, 27, 31.

BRAIN—INJURIES AND COMPLICATIONS

See also B.S.P., Vol. 2, p. 349, S. Key 74.

Major closed head injuries

Metabolic disorders

HIGGINS and his co-workers (1954) have studied the occurrence of metabolic disorders in 76 consecutive patients with major closed head injuries who had remained unconscious for more than 12 hours after injury. In the first 12 hours, the patients received no fluids, except blood transfusions when indicated; tube-feeding was begun within the next 12 hours and continued until the patient could swallow easily. The intravenous route was found to be necessary only in 2 hypochloraemia patients who were given plasma transfusions. Fluid feeding began with water or diluted milk, followed by a milk-glucose-water régime designed to provide adequate caloric and fluid intake, but with insufficient protein and sodium to raise the blood-urea and plasma-sodium levels until the metabolic condition had been ascertained. Modifications were made when required. Estimations were made, during the period of coma, of blood-urea, plasma-chloride plasma-bicarbonate, plasma-protein, serum-sodium, serum-potassium, and serum-calcium, and the urinary *pH*, specific gravity, chloride and urea; the urinary sodium and potassium ion levels were also estimated in about one-third of the patients and the blood-sugar level in 69 cases. Patients were divided into 3 groups: Group 1, comprising 8 patients, remained biochemically normal from the time of injury to the time of recovering consciousness. Group 2, consisting of 50 patients who showed transient biochemical abnormalities which disappeared spontaneously without specific therapy; and Group 3, comprising 18 patients who, in addition to transient abnormalities, showed more severe biochemical disturbances which were persistent and progressive unless reversed by specific therapy. Transient disorders included proteinuria, hyperglycaemia, renal glycosuria, raised blood-urea level and low total plasma-protein level; the major disorders were hyperchloraemia, with hypochloruria, water deprivation, respiratory alkalosis and renal uraemia. The findings suggest that metabolic disorders play a part in the mortality of head injury.

Higgins, G., Lewis, W., O'Brien, J. R. P., and Taylor, W. H. (1954). *Lancet*, 1, 61.

BREAST—CARCINOMA OF

See also B.S.P., Vol. 2, p. 456, S. Key 77.

Treatment

Spread of secondaries to internal mammary lymph nodes

HANDLEY and THACKRAY (1954) discuss the spread of secondaries from breast carcinoma to the internal mammary lymph nodes. They had already found that dissection of the internal mammary chain during a radical mastectomy gave useful information. The afferent lymphatics from the breast pierce the intercostal muscles usually close to the anterior perforating arteries, and the lymph nodes lie behind these muscles, being inconstant in number and position. After incising the intercostal muscles, it is found convenient to detach the lymph nodes with two pairs of dissecting forceps. It is usually easy to avoid injury to the internal mammary artery or to the pleura. In a series of 150 cases in which all diagnoses were based on histological evidence, no mortality occurred in the 139 patients who were operable. In the remaining 11 inoperable cases, 8 showed invasion of the chain. It was found that with the greater degree of axillary involvement the more likely was invasion of the internal mammary chain. Three-quarters of the patients with metastases only in the axilla survived 3 years after operation, but only one-third of those with both axillary and internal mammary metastases now survive. Prognosis is not hopeless when the internal mammary chain is invaded for surgical excision and radiotherapy together improve the outlook. Some surgeons excise the rib cartilages to facilitate excision of the internal mammary chain, but in doing so lose the advantages of the monoblock operation, but if the pleura is deliberately opened such an operation becomes possible and has given good results.

Ovarian activity in breast cancer

Effect on survival

Removal or atrophy of ovaries.—The effect of ovarian activity on survival in breast cancer is discussed by SOMMERS, TELOH and GOLDMAN (1953). In a group of 100 cases of breast

cancer seen at autopsy four-fifths were found to have abnormal ovaries, sometimes with hyperplasia of the cortical stroma indicating active secretion of some steroid hormone

secretion After removal of the ovaries they regressed or became dormant for some months. In addition to the ovaries the adrenal cortex is probably involved in the mechanism described, and some surgeons have already performed bilateral adrenalectomy for breast cancer

Glandular metastasis

Post-operative occurrence

ANDREASSEN, DAHL-IVERSEN and SØRENSEN (1954) discuss glandular metastases in breast carcinoma, hitherto divided into 2 stages, depending upon the microscopic presence or absence of carcinoma in the axillary glands. In Stage 1, 80 per cent of the patients remained free from recurrence for 5 years, in Stage 2, only 20–40 per cent after 5 years. Recently, however, this classification has been superseded by one based upon the state of the supra-

assuming that the radical operation in severe cases encourages metastases The present

BURNS AND SCALDS

See also B S.P , Vol 2, p. 518, S. Key 82.

Burns

Treatment of the neglected burn

Fluid and protein loss.—A group of plastic surgeons (1954) discuss treatment of the neglected burn Their commonest finding is a poor general condition, and it is stressed that anaemia, hypoproteinaemia and infection hinder recovery, particularly in burns of the whole skin covering more than one-tenth of the body surface. In such extensive lesions secondary anaemia generally occurs, presumably due to a temporary dysfunction of the bone marrow

amino acids may prove helpful and be introduced by stomach tube if necessary. If the carbohydrates are too low ketosis readily develops. A diet of about 3,000 calories with added salt and vitamins is indicated for adults Infection should be treated by removal of dead tissue as soon as possible, irrigation of the wound and careful drying. Antibiotics and skin grafts are required in most cases, and during and after healing physiotherapy and occupational therapy to restore normal movement.

Sub-Committee of the British Association of Plastic Surgeons (1954). *Lancet*, **1**, 257.

COLITIS

See also B S P., Vol 3, p. 88, S. Key 97.

Ulcerative colitis

Surgical management

BACON and TRIMPI (1953) discuss the surgical management of ulcerative colitis The co-operation of all fields of therapy is shown by the diminishing frequency with which seriously ill patients reach the operating table too late for surgical measures. This fact is demonstrated by the remarkable fall in surgical mortalities in ulcerative colitis and by the fall in the incidence of emergency ileostomies. In the authors' series of 331 patients with chronic ulcerative colitis, 81 underwent surgical intervention. The post-operative mortality was 5, or 3-4 per cent, in 137 operations performed; 4 of the deaths occurred prior to 1946, as the result of emergency ileostomies in practically moribund patients In the last 5 years, emergency loop ileostomies have been necessary in only 2 cases, the remaining patients in this period reaching hospital in time for intensive whole blood transfusions, and antibiotic and electrolyte administration prior to operation, ileostomy and colectomy have been performed in one stage in the majority of this group, with no post-operative mortalities and with a significantly shortened convalescence. The authors emphasize the importance of those cases of long-standing illness in which the patients experience periodic exacerbations and remissions, and are never ill enough to require immediate operation, but eventually either become totally disabled or die as the result of secondary complications. The low surgical risk of colectomy and the inconvenience of a permanent ileostomy should be considered in comparison with the benefits of cure of the disease, removal of pre-cancerous bowel, prevention of thrombo-embolic disease, and reversal of degenerative liver, kidney and arthritic changes. The authors recommend a 2-stage operation: (1) ileostomy and colectomy to the low sigmoid colon, and (2) abdomino-perineal excision of the rectum and distal sigmoid The operation was performed on 45 patients, with complete rehabilitation of 41, including 2 mothers who have since experienced normal pregnancies

Total colectomy

One-stage procedure including abdomino-perineal resection and primary ileostomy

Criteria for surgery, operative management of the patient.—One-stage total colectomy, including abdomino-perineal resection, with primary ileostomy, in the surgical treatment of chronic ulcerative colitis and familial polyposis is discussed by PALUMBO and RUGTIV (1953). Surgical treatment is necessary in 10-20 of cases of the former condition, and in 100 per cent of the latter, and the general trend in both groups is towards the performance of subtotal or total colectomy by a multiple-staged procedure. The high incidence of malignancy in cases of polyposis demonstrates the need for colectomy, in this disease, as soon as the diagnosis is established. In chronic ulcerative colitis, the need for surgery depends on several factors, including: irreversible anatomical and functional changes; chronic sepsis in the colon, obstruction, perforation abscess, and ano-rectal complications. The authors have performed a one-stage total colectomy (including removal of the rectum and anus) with or without preliminary ileostomy, in 9 patients, and, in 2 patients, a sub-total colectomy with an ileo-rectosigmoidostomy A preliminary ileostomy was necessary in 2 cases, as these cases were operated on late and in an acute septic stage, both improved considerably, so that a one-stage colectomy could be performed safely later All the patients were ambulant on the first post-operative day, the only complications were one retroperitoneal abscess and a homologous serum hepatitis The operation was performed through a transverse, elliptical, supra-umbilical or infra-umbilical incision, without post-operative hernia or other wound complications. There were no operative or post-operative deaths. The authors emphasize the importance of proper protein, fluid, electrolyte, and whole blood replacement A careful dissection close to the bowel wall during the abdomino-perineal resection minimizes damage to the autonomic nerve supply to the bladder and associated structures, thereby preserving normal bladder and sexual functions post-operatively.

Bacon, H. E., and Trimpi, H D. (1953). *J Amer med. Ass*, **153**, 1249.
Palumbo, L. T., and Rugtiv, G. M. (1953). *Arch. Surg., Chicago*, **67**, 762.

COLON—DEVELOPMENTAL ABNORMALITIES AND MEGACOLON

See also B S P., Vol 3, p. 130, S. Key 99

Hirschsprung's disease

Treatment

and a preliminary x-ray showed distended loops of small intestine filled with gas The barium took 19 hours to reach the colon In the following weeks some improvement occurred, assisted by enemas, but spontaneous meteorism was frequent Operation was performed

DIVERTICULA OF THE ALIMENTARY TRACT

See also B.S P, Vol 3, p 256, S. Key 109.

Meckel's diverticulum

Intussusception

Differential diagnosis Meckel's and ordinary acute intussusception —Intussusception due to Meckel's diverticulum is discussed by HOLOWACH, THURSTON and McCOY (1953) An

abdominal mass is less constantly found, as most of these cases remain enteric, or seldom

characteristically, an older age incidence, previous abdominal complaints, and frequent enteric intussusception The morbidity and mortality were markedly increased in comparison *with 107 cases of intussusception without Meckel's diverticulum*

Holowach, J, Thurston, D L., and McCoy, E. E. (1953) *Arch. Surg, Chicago*, **67**, 699

EYE IN RELATION TO ENDOCRINE DISTURBANCE

See also B S P, Vol 3, p 453, S. Key 139.

Malignant exophthalmos

Quantitative analysis of orbital tissues

A quantitative analysis of the orbital tissues in malignant exophthalmos is presented by

RUNDLE, FINLAY-JONES and NOAD (1953). A male patient, aged 69 years, with malignant exophthalmos, was admitted to hospital for investigation and died 13 days after admission; necropsy was performed 12 hours after death. A study of the orbital tissues from the patient was made, histologically and biochemically, and the results were compared with data obtained from control male subjects who had died in a state of normal nutrition, and with data from 3 male thyrotoxics all severely exophthalmic. The ages of the controls ranged from 17–74 years (mean 42 8+18); the ages of the thyrotoxics were 35, 54 and 55 years respectively. The data revealed that in malignant exophthalmos the orbital tissue bulk is clearly greater than in both controls and thyrotoxics. The estimated degree of orbital filling is correspondingly raised, the conclusion is supported that in malignant exophthalmos there is overcrowding of the orbital cavity, causing extreme protrusion of the globe and lids It was further demonstrated that the excess bulk of the orbital tissues is due solely to enlargement of the orbital muscles, the residue remaining normal in weight. Individual muscles were increased to 2–5 times their normal weight, and were affected symmetrically. Histological examination showed that the muscle fibres were enlarged and degenerate, but not increased in number, and that there was a considerable increase in the connective tissue elements. The present findings may be considered in connexion with the unitary concept of Graves' disease: if the orbital changes differ, the basic hormonal upset may be different in the 2 conditions or the response of the end-organ, the orbital tissues, to the same hormone, may differ; or 2 closely-linked hormones may be present, usually, in roughly inverse proportions, that predominating in thyrotoxicosis being lipotropic and thyrotropic and that in malignant thyrotoxicosis acting as an abnormal growth hormone on the orbital and perhaps other muscles. The spontaneous ophthalmic types may be the result of absence of the lipotropic and thyrotropic factor.

Rundle, F F., Finlay-Jones, L. R., and Noad. K. B (1953). *Aust. Ann. Med.*, 2, 128.

FACIO-MAXILLARY INJURIES AND DEFORMITIES

See also B.S P , Vol. 4, p. 15, S Key 148.

Fractures of nasal pyramid

Treatment

Sequelae.—LOWENTHAL (1953) reports on mild and moderately severe fractures of the nasal pyramid and zygomatic areas, which are described as lesser facial fractures. He emphasizes the fact that such fractures are significant because of the functional and cosmetic sequelae which may result if reduction is inadequate Common functional sequelae include disturbances of the respiratory, olfactory, visual, masticatory, and neurological systems; there are often psychological complications also From the cosmetic point of view unpleasant sequelae include nasal, ocular, and facial asymetry, as well as ugly scar formation of the soft tissues. The author presents detailed procedures for the diagnosis of facial fractures, and a table is included presenting the diagnostic value of various radiographic views The diagnostic criteria for the various specific fractures in the nasal pyramid and zygomatic areas are also discussed. On the question of treatment, it is first emphasized that in the repair of soft tissues, particular attention must be paid to the closure of the folds and orifices of the face Ugly scar tissue formation and notch deformities of the nares can be minimized by meticulous care in wound closure. The treatment of nasal pyramid fractures is described. The author states that the first step in the treatment of external deviations and depressed frontal fractures is release of impaction. The fracture must be mob[illegible] reduced The second step is elevation and straig[illegible] nasal bone and frontal proce[illegible] and extern[illegible] the pyr[illegible] arch fr[illegible] fracture[illegible] approac[illegible] antral, a[illegible] instances [illegible] multiple approaches are necessary [illegible] one being preferred for different phases of treatment [illegible] temporal, the inferior orbital, the trans- [illegible] several routes. The author is of the opinion that special consideration [illegible] before satisfactory results [illegible] In many nasal injuries in children, because of the possibility [illegible] recognised and treated. Nasal injuries are sometime[illegible] usually occur in the columellar portion of the sept[illegible] and if this procedure is not successful on the first atte[illegible] repeated within several days.

Complex fractures of the middle third of the face

Treatment

Restoration of function and fracture reduction —Complex fractures of the middle third of the face and their early treatment are discussed by DAWSON and FORDYCE (1953). A review has been made of 190 cases of fractured maxilla (bone injuries to the central middle third of the face excluding separate local injuries to the nose) admitted to a single unit. In the treatment of these injuries, restoration of function necessitates replacement of the tooth-bearing areas, reduction of nasal fractures and straightening the deformed nasal septum, and correction of associated depressions of the malar, the ultimate appearance of the patient will depend on accurate replacement of the bones, and accurate replacement is also essential in controlling cerebrospinal rhinorrhoea and avoiding pharyngeal obstruction. The authors recommend the use of Le Fort's classification, 34 per cent of the present series were Le Fort II and 23 per cent were Le Fort I The maxillary block may be impacted upwards and backwards, or it may be free and therefore termed "floating"; lateral displacement is common; gagging of the bite due to downward displacement posteriorly is found frequently; spasm of the medial and lateral pterygoid muscles, from fracture of their bony origins, causes a downward and backward pull on the separated fragment and accounts for the trismus often observed It is emphasized that, save in very exceptional circumstances, reduction without fixation is

plegia followed cases with associated cranial injuries. There were 7 deaths, all within 5 days of admission and within 9 days of the accident; no operative reduction or fixation had been performed in these cases

Dawson, R. L G , and Fordyce, G L (1953). *Brit. J. Surg* , 41, 254.
Lowenthal, G (1953) *Ann Otol , etc., St. Louis*, 62, 995.

FRACTURES, DISLOCATIONS, FRACTURE—DISLOCATIONS AND ALLIED INJURIES

See also B S P., Vol 4, p 165, S. Key 157.

Ankle

Pronation dorsiflexion fracture

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natively from the anterior lip of the tibia but when the latter is found study of the literature shows that a fracture in the base of the medial malleolus is always present In falling the patient sustains a sudden impact on the sole so that the foot is vigorously dorsiflexed and the trochea, shaped like a truncated cone, acts like a wedge and fractures the base of the medial

surface After the first stage of the fracture successive stages were the evulsion of a large fragment from the anterior lip of the tibia, fracture of the supramalleolar part of the fibula and in the fourth stage transverse fracture in the dorsal part of the tibia level with the proximal margin of the large tibial fragment It is generally noted that the anterior lip of the tibia forms bony union very slowly and no weight bearing is permissible for about 15 weeks or it may cause the talus to slide forward on the somewhat oblique distal articular surface of the tibia In a stage four reduction a plaster cast may be used as in the earlier stages but continuous traction by a wire through the calcaneus is needed to prevent lateral displacement and abnormal angulation

Hip dislocation

Shelf operation

WIBERG (1953), writing on shelf operation for hip dislocation, says that when poor results

have been obtained in cases of close or open reduction this operation is designed to give further protection For patients of 2 to 3 years of age with congenital hip dislocation a closed reduction is attempted first. Both hips are put in plaster in the frog position for 3 months after reduction If this proves unsuccessful, open reduction is performed but without the addition of a shelf. The patient is then observed by regular rontgenographic studies for many years. Shelf operation is done only when redislocation occurs, or when the development of the acetabulum roof shows a defect with subluxation of the head. Reduction should not be performed after the age of 8 years because of the risk of necrosis of the femoral head. The best treatment is a high shelf operation A roof is made but the head's position is not altered When the shelf operation is done for dysplasia of the hip joint, with or without subluxation, the new roof must reach the femoral head if symptoms are to be relieved. If placed too high, the joint will not be affected, if too low, pressure necrosis of the joint capsule will result.

Femoral neck

Non-united and recent fractures

Treatment.—WESTERBORN (1953) describes treatment of non-united and recent fractures of the femoral neck by arthroplasty, using Judet's method Nailed fractures of the femoral neck sometimes do badly, developing pseudarthrosis or necrosis of the femoral head with subsequent arthritis Various authors describe this complication in cases varying from 9 to 74 per cent of their series. Necrosis may be mild and not justify further intervention, but is often so severe as to necessitate arthroplasty, those developing pseudarthrosis of the femoral neck suffer most, developing marked disability. This complication is not infrequent in middle-aged or even young persons. The introduction of acrylic prostheses is an improvement on previous treatments, and may give better functional results than the Smith-Peterson mould arthroplasty, but it can only be used when most of the femoral neck is intact It appears that the late prognosis of nailing for fractures is immediately impaired if the fragments are not accurately aligned Good results are more probable if the normal or valgus position is restored. There are other causes of re-dislocation which, if slight, may heal without further surgery, but if it is considerable reposition may be needed to facilitate healing, though this does not occur easily and only about half the patients thus treated show good results. The writer has decided to employ arthroplasty by Judet's method for medial fractures of the femoral neck, for cases of pseudarthrosis when the fracture is near the head, for patients in whom re-dislocation justifies further operation, and also for those in whom satisfactory contact between the fragments is unobtainable The method is also used in recent cases in which restoration of the varus position could not be obtained So far 12 patients had been treated on these lines, some of whom were advanced in years Freedom from pain, improved movement, and with these an improved general condition, have been marked.

Wrist injury

Carpal navicular bone

Treatment.—BRANSON (1953) states that x-ray studies using multiple projections are required in order to establish an accurate diagnosis of fracture of the carpal navicular bone. The presence of this fracture should be suspected in every wrist injury associated with hyperextension If the injury remains painful for more than 2 weeks a fracture is probably present At the time of the injury it is not always possible to demonstrate the fracture by means of x-rays Sometimes the fracture line is seen clearly when calcium absorption has taken place As for treatment, it is necessary to immobilize the first metacarpo-phalangeal joint, the wrist and the distal three-fourths of the forearm A skin-tight cast is applied with the wrist and thumb joints in the position of function, thereby permitting the use of the hand and avoiding atrophy. Immobilization should be maintained until the fracture fragments have healed. X-ray examination should be carried out 2 weeks after removal of [illegible] If the skiagram reveals a more evident fracture line it may be d[illegible] plete and that the cast must be reapplied When Brans[illegible] in the treatment of 32 cases of fracture of the proxim[illegible] one, healing was recorded in 30 cases. Eight fractures healed i[illegible] months and 18 fractures healed in 4–6 months Healing occurred in 4 patients after more than 6 months' immobilization, and in 2 cases healing had not been effected after 6 months.

Internal derangements of temporomandibular joint

Differences from knee-joint lesions

Internal derangements of the temporomandibular joint are discussed by CHRISTIE (1953) Although a parallel has been drawn between these lesions and those in the knee-joint, there

... attached all round its periphery

prone to follow recurrent locking, is probably also applicable to the temporomandibular

benefit by the consequent scarring and tightening of the capsule The incisions ... are based on the transverse line of the zygoma above the joint.

Branson, E C. (1953) *New Engl J Med*, **249**, 884.
Christie, H K (1953) *J int Coll Surg*, **19**, 704
Lauge-Hansen, N (1953) *Arch Surg (Chicago)*, **67**, 813.
Westerborn, A (1953) *Acta chir scand*, **106**, 381
Wiberg, G (1953) *Mod Med Canad*, **8**, No 9, 85

GALL-BLADDER AND BILE PASSAGES

See also B S.P , Vol. 4, p. 238, S Key 161

Gall-bladder disease

Indications for surgery

Interpretation of symptoms —The indications for surgery in gall-bladder disease are ...

The author considers that a more liberal attitude towards cholecystectomy ... gall-stones will reduce the incidence of complications in older ... Exploration of the common duct was found necessary in 51 per cent of ... patients, and almost one-half of the ducts explored revealed one or more stones.

Common bile duct

Idiopathic dilatation

Signs and symptoms and treatment by choledocho-duodenostomy —A case of idiopathic dilatation of the common bile duct (congenital choledochal cyst) is reported by ...

and CHERRY (1953). The patient, a Japanese boy aged 14 years, complained ch gastric pain, slight fever, and malaise. Examination revealed an icteric sclera and of the liver. The results of liver function tests were equivocal, although sugges obstructive type of jaundice The patient was then discharged from hospital, bu later he was re-admitted, the symptoms were more severe, the jaundice more pro and a mass was felt in the right upper quadrant. Operation revealed a cystic ma appeared to be a dilated common duct; the hepatic ducts were approximately 2 i diameter, the cystic duct about 1 inch in diameter, and the common duct, in its low portion, 4–5 inches in diameter. The mass extended into the true pelvis; the duoden drawn tightly across the cyst. Aspiration of the cyst produced 2,200 millilitres of thin, gr bile. The collapse of the cyst facilitated the performance of an anastomosis, 2 inch length, between the cyst and the duodenum. It is anticipated that a permanently good r will be obtained, although 2 years after the operation the patient had a mild attack cholangitis, with slight fever and barely perceptible jaundice, lasting about 3 days. authors emphasize the importance of recognition of the condition at the time of surgery a of treatment by choledocho-duodenostomy

Burgess, C M, and Cherry, J W. (1953). *Arch. Surg., Chicago*, 67, 771.
Zollinger, R M (1954) *Cincinn J. Med.*, 35, 1.

HAEMOPHILIA AND OTHER HAEMORRHAGIC STATES

See also B S P, Vol 4, p. 366, S Key 176

Aetiology

Circulating anti-coagulant as causative factor

A case of haemophilia-like disease, produced by a circulating anti-coagulant, is recorded by COLLINS (1953) A Chinese female patient, aged 62 years, suffered from spontaneous bruising, without the occurrence of any external haemorrhage She had had 5 normal confinements, and had never undergone any operations, experienced any serious illnesses or haemorrhagic disorders, or had a blood transfusion, none of her family had any haemorrhagic tendency Examination revealed no abnormality in the cardiovascular system, and all the haematological values tested were normal except for a prolonged coagulation time of 28 minutes. The laboratory studies revealed a grossly deficient consumption of prothrombin during the process of coagulation The combination of prolonged coagulation and impaired -othrombin consumption is similar to the findings in haemophilia, and indicates the presence the patient's blood of a haemophilia-like abnormality, the result of a test showed this ıormality to be due to a circulating anti-coagulant The result of a further experiment luded anti-thrombic activity in the patient's plasma, tests with protamine sulphate ved that the anti-coagulant was not heparin-like in its action. Investigation also showed the anti-coagulant acts on the first phase of coagulation The results of the study suggest that the anti-coagulant was not an anti-thromboplastin by opposing anti-haemophilic globulin. The anti- acts by opposing platelet factor than ... it seems more likely that it coagulant is heat stable, being unaffected by heating at 60°–65° C. for 5 minutes It is stable to storage, showing only moderate impairment of its action after 3 months at 5° C. A number of instances of anti-coagulants affecting the earlier part of coagulation have been recorded, the cases comprising 3 main groups. (1) haemophilic patients who have become refractory to blood transfusions, (2) non-haemophilic males, and (3) female patients.

Collins, I S. (1953). *Aust Ann Med.*, 2, 161

HERNIA

See also B S P., Vol 4, p. 248, S Key 180

Intersigmoid hernia

Diagnosis and treatment

THOMSON and ROBINS (1953) report a case of intersigmoid hernia Literature records 26 such cases, 21 presenting as acute obstruction, the remainder as chronic. The intersigmoid fossa lies under the sigmoid colon, the pouch behind the mesocolon, with its orifice facing interiorly and to the left, and appearing as a mere peritoneal dimple, or as a small sac. A man of 70 was admitted with a 48-hour history of intermittent abdominal cramp near the umbilicus, with some nausea and vomiting There was slight abdominal distension, but no visible peristalsis. Some constant tenderness was present below, and to the left of, the umbilicus Radiography revealed one moderately dilated loop of jejunum in the mid and lower abdomen A diagnosis of partial small-intestine obstruction of unknown cause indicated la

The peritoneal cavity contained excess of clear straw-coloured fluid. The small intestine was

Between these, the bowel was red and oedematous, with thrombosed mesenteric vessels. More distally, it was grey-white, contracted and rather empty. Exploration of the lower abdomen for the source of obstruction revealed a large intersigmoid fossa, admitting the index finger. The cause of obstruction, therefore, appeared to be herniation of the jejunum into the intersigmoid fossa

Thomson, F. B, and Robins, R E (1953) *Ann Surg*, 138, 917.

HODGKIN'S DISEASE, OTHER RETICULOSES, RETICULO-SARCOMA AND MYELOMATOSIS

See also B S.P., Vol. 5, p. 2, S Key 185.

Hodgkin's disease

Mammary disease

Treatment.—Six cases of Hodgkin's disease of the breast are reported by KUNKLER (1954). These cases were seen within a period of 6 months at a hospital registering 50–60 new cases of Hodgkin's disease each year, a fact which may be explained by selection in the type of patient referred to a radiotherapy centre The ages of the patients were 64, 39, 28, 53, 25 and 25 years respectively The condition may be indistinguishable, as regards local signs,

Kunkler, P B. (1954) *Med Pr*, 231, 38

HORMONES

See also B.S P., Vol 5, p 29, S Key 186

Hypothyroidism

Diagnosis

Use of thyrotropin.—JEFFERIES and his colleagues (1953) discuss the value of a single

hormone it was concluded that the patient's condition was not due to primary disease of

test was performed 3 times in one patient without producing an antihormone effect. Exposure to iodine, as may occur when the skin is painted with tincture of iodine, may mask the response to thyrotropic hormone In these circumstances, however, the response may be detected by establishing the presence of an increased amount of protein-bound iodine in the serum This chemical test is comparatively difficult to determine and it should be reserved for special investigations

Jefferies, W M K , Levy, R P , Palmer, W. G , Storaasli, J. P., and Kelly, L. W., Jun. (1953). *New Engl J Med*, **249**, 876

INTUSSUSCEPTION

See also B S.P , Vol. 5, p. 160, S Key 200

Intussusception in adults

Aetiology

Intussusception in the adult, particularly of retrograde type, is described by Deterling, O'Malley and Knox (1953). An analysis of 40 cases is made and in this group half the patients had passed the sixth decade In adults some malformation or tumour is found in most cases, and in the writers' series, 16 patients had malignant and 8 benign growths. The malignant lesions are usually adenoma, carcinoma and sometimes sarcoma. The benign included cases of lipoma, adenoma, polyp and neurofibroma. Though not found in the writers' series, *Meckel's diverticulum is a not uncommon cause of the condition. In the literature*
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In 2 cases the presence of fixed matted loops of bowel not far from the end of the Miller-Abbott tube seem to be associated with the reverse intussusception, and in 2 other cases the too rapid withdrawal of a tube, which had progressed far down the intestine, seemed to

Deterling, R A , Jun , O'Malley, R D , Knox, W. (1953). *Arch. Surg , Chicago*, and 6, 854.

KIDNEY AND URETER—GROWTHS

See also B.S P., Vol 5, p 268, S. Key 210

Haemangioma of kidney

Treatment

Haemangioma of the kidney is an uncommon condition, only about 70 cases having been reported in the literature A 47-year-old woman was seen by Anderson, Hancock and [illegible] (1953), complaining of persistent painless haematuria of 24 hours duration, in

oedematous,
titial haemo-
cause haema-
ore common

Neuroblastoma of kidney

In association with horseshoe kidney

Diagnosis.—TAYLOR, RUSSO and JACOBSON (1953) describe a case in which a neuro-

An excretory urogram showed the right kidney to be rotated so that the pelvis lay laterally, and the left kidney was also on the right, lying below its fellow. The left ureter, however,

patient
later. H
kidney
in the p
in children are discussed

Perinephric cysts

at 15 months of age, it had obtained the size of a large grapefruit The lump filled the left side of the abdomen, being firm and lobulated The blood pressure was 140/80, and the haemoglobin was 9 5 grammes per cent Other investigations were normal During urography the left kidney did not secrete the dye, the right kidney functioning normally A retrograde pyelogram revealed hydronephrosis of the damaged organ After transfusion, nephrectomy was performed The blood pressure rose to 150/100, but post-operative recovery was excellent The specimen consisted of 2 cysts connected by a short fistula, 1 being 8 times the size of the other. The larger had a fibrous wall with a smooth lining, the smaller a fibro-muscular wall The partition between the cysts consisted of degenerating renal tissue A thin cap of suprarenal tissue surmounted the specimen The authors believe that the condition began *in utero* with a congenital stenosis of the ureteropelvic junction, which gave rise to a hydronephrosis Disruption of the pelvic wall allowed urine to accumulate in the perinephric space with the formation of the perinephric cyst The child failed to attend for follow-up, but is said to be growing normally. The classification of perirenal cysts is reviewed.

Renal hypoplasia

Intravaginal ureteral orifice

Result of operation —Describing a case of renal hypoplasia with an intravaginal ureteral orifice, CECIL (1953) says that the patient, a child aged 7, had normal micturition, but had, nevertheless, been persistently wet Instrumental examination demonstrated a normal left ureteral orifice, but the right one was found in the upper vagina above a small constriction. Pyelography showed that the abnormal ureter began at the level of the second lumbar vertebra, no pelvis being visible Excretion tests showed that the output of the abnormal kidney was extremely small, so a right nephrectomy was performed. The removed kidney consisted of a cap of tissue less than an inch long on the very small ureteric pelvis On section definite lobulation could be made out, one lobe being larger than the rest Microscopic

Polyarteritis nodosa

Symptoms, diagnosis and treatment —ZISK (1953) describes a case of polyarteritis nodosa in which the renal involvement necessitated removal of a kidney. A woman of 28 years

presented with acute abdominal pain and pyrexia, associated with a leucocytosis. Small red raised nodules appeared on both legs, and biopsy specimens [illegible] necrosis, [illegible] been inva[illegible] chemothe[illegible] She receiv[illegible] headache, [illegible] functionle[illegible] ...ked ureter. The kidney was explored, and found to be greatly enlarged, with a calcified ureter. It was accordingly removed The pelvis and calyces were greatly distended, and the renal tissue had thinned out. Histology showed all stages of polyarteritis in the renal vessels, scattered glomerular destruction and generalized tubular atrophy [illegible] disease, [illegible] be consi[illegible] biopsy, e[illegible] is alway[illegible] ...eosinophilia, as well as a leucocytosis, but the chemistry of the blood is unchanged The prognosis in polyarteritis nodosa is grave, a period of ill-health terminating whenever a vital organ is involved.

Anderson, J. B. Lee, J. J., Hancock, R. A., and Black, S. R. (1953). *J. Urol*, 70, 869.
Cecil, A B (1953). *J Urol.*, 70, 835.
[illegible]
[illegible] *Urol.*, 70, 864.
[illegible]

KIDNEY AND URETER—STONE

See also B S P , Vol 5, p. 297, S Key 212.

Non-opaque urinary calculus

Diagnosis

Radiological techniques.—Discussing the problem of the non-opaque urinary calculus, Higgins (1953) points out that any stone must have greater radio-opacity than that of the soft tissues before it can be seen in a plain x-ray Pure stones, containing only one crystalloid, are rare, careful analysis nearly always revealing traces of other substances Accordingly, it is rare to find a truly non-opaque calculus, but relatively non-opaque calculi are more common Various articles say that between 2 and 15 per cent of renal calculi are invisible on a plain film Good preparation, positioning and absolute immobility of the patient are essential, and the lowest voltage possible should be used, with good technique, most renal stones 2 millimetres in diameter or more may be seen. In the ureter, 3 millimetres is the critical size. Here the figures for invisible stones vary from 1 to over 20 per cent. The most frequent position for a stone invisible on plain x-ray is just above and medial to the ischial spine. Considering vesical calculi, the author believes that radiology is of limited diagnostic use, for over 50 per cent of these are not sufficiently opaque to show through the relatively opaque pelvic structures, and cystoscopy should always be employed in those cases suspected of having bladder stones Stereoscopic pictures give more accurate information than single ones, and the Bucky diaphragm should always be used Excretory urography more frequently demonstrates stones than the retrograde variety, and a delayed film sometimes shows a stone that has absorbed the medium on to its surface The author advocates the use of air pyelo-ureterograms where other methods have failed to show the stone.

Higgins, C C (1953). *J. Urol*, 70, 857.

MELAENA AND BLOOD IN THE STOOLS

See also B S.P , Vol. 6, p 56, S Key 231.

Occult blood in faeces

Tests

Hepler, Wong and Pihl (1953) discuss the value of various tests for occult blood in the faeces Tests were performed on 212 stools derived from 120 patients, including 40 patients suffering from lesions of the gastro-intestinal tract The results were compared with those obtained in normal persons Smears and emulsions of faeces were examined, and in some cases the emulsions were boiled and filtered, thereby eliminating the possibility of producing false positive reactions. Quantities of reagents were measured carefully, and glassware was [illegible]

solution of benzidine base. Adler's test depends upon the reaction between benzidine base

reaction is easy to read and the benzidine dihydrochloride reagent is not likely to deteriorate.

Hepler, Opal E., Wong, Peggy, and Pihl, Helen D (1953). *Amer. J. clin. Path.*, **23**, 1263.

MOUTH AND PHARYNX—MALIGNANT DISEASE OF

See also B S P., Vol. 6, p 82, S. Key 234.

Epithelioma of the chin

Treatment

Radon seeds.—DOWNING and FOLAN (1953) report on the extrusion of 2 radon seeds which had been inserted during the course of treatment for an epithelioma of the chin The case occurred in a woman aged 45 years After a recurrence of the growth 4 radon seeds were inserted and this treatment proved to be successful Sixteen years later, however, the healed area became inflamed and ulcerated Two metal seeds appeared at the surface of the ulcer and were removed by the patient Evidently the seeds had been forced to the surface by movements of the tissues overlying the bone X-ray examination of the lower jaw revealed the presence of 2 metallic objects in the tissues anterior to the bone One of these objects was situated in the superficial tissues and appeared likely to reach the surface in the near future. No evidence of carcinoma was detected. The authors point out that, in contrast with radium needles, which must be removed, radon seeds are often left *in situ* permanently Occasionally the seeds slough out spontaneously Extrusion may occur if the seeds are placed too near the surface or if the tumour is in a state of necrosis and ulceration

Carcinoma of floor of mouth

Symptoms and treatment

Results of treatment.—Carcinoma of the floor of the mouth is discussed by WINDEYER (1953) A study was made of 131 patients who attended hospital during the years 1931–1946. The ages of the patients ranged from 38–82 years, almost one half of the patients were aged 60–69 years, there were 118 men and 13 women The most frequent associated abnormality in the mouth was patchy leucoplakia; any teeth present were usually in very poor condition, with gross infection around the gums, leucoplakia and dental sepsis were, however, by no

cases which were too advanced, no treatment was given, 3 were treated as regards the primary

complication of radiotherapy

Difficulties in diagnosis

applicators *nor* x-rays at the conventional 250 kilovolt or the low-voltage contact, have been extensively used or have given s
radium or surgery. A total of 97 patients

depend on early diagnosis, and on advances in radiotherapy and in surgical methods, especially those of closure of wounds

Bilateral neck d

(2) operation on the neck, and (3) *syncope*; during the inquiry, considerable stress was placed on the question of whether the internal jugular veins had been actually ligated at the

is followed by various degrees of compensation, a permanent "fat face" may be expected in some cases, and (3) the effect of bilateral jugular removal on cerebrospinal fluid pressure cannot be stated from these observations, but no serious alterations have been noted. The removal of the sterno-mastoid *in toto* gives ready access to the pharynx and larynx, the application of Crile's clamp to the common carotid and to the upper part of the internal jugular vein prevents bleeding. Radium should be left in the wound if there is doubt as to the complete removal of glands, especially those deep in the carotid.

Post-treatment results

Carcinoma of the floor of the mouth is discussed by GARDHAM (1953) A study of the records of 72 patients, treated at University College Hospital, reveals 2 important facts: 27–28 per cent of the patients lived for more than 5 years and are still living, free from recur-

group, although "curable" cases showed no common factor in history or physical signs, pre-selection by histological methods may become more important in the future. Of the 39 "failures", 16 were classified as "operable", 8 as doubtfully "operable", and as "inoperable"; selection of cases for operation should not be too rigid, and the recurrence rate of

is very wide in comparison with the size of the ulcer, and cases in which the bone of the

a temporary tracheotomy at the conclusion of the main operation; gastrostomy should be used more widely than it is Cellulitis of the neck has not been encountered since the end of the last war, fistula formation and septic pulmonary complications still occur. Eventual functional recovery, even after the most extensive operations, is surprisingly good. The author is satisfied if his patients can talk intelligibly, swallow solid food, and mix with others without being conscious of a gross deformity, speech is usually very difficult for 1 week, indistinct for 3 months, and good enough for all ordinary purposes shortly after this

X-ray implants and moulds

Technique of application—The treatment of carcinoma of the floor of the mouth is described by DOBBIE (1953). Radium treatment of the primary growth is separated from treatment of the secondary lymphatic extension which, whenever possible, is dealt with by block dissection. Appropriate techniques of primary treatment are applied individually to each patient Moulds and implants are used by the author in nearly equal proportions;

of the jaw can easily be included in an effective radiation field The method is suitable to lateral and forward extension, and for some cases of backward extension into the tongue if the outer mould is replaced by a submental plane of implanted radium In about half the cases, however, a satisfactory mould is impossible, and implanted radium must be used, needles 4–5 centimetres long are passed through the tongue into the floor of the mouth. The radon implant in gold seeds is particularly suitable for small and superficial lesions and for the aged. These methods restore the mouth to normal without tissue loss or need for

Cade, S. (1953) *Brit. J Surg*, 41, 225
Dobbie, J. L. (1953) *Brit J Surg*, 41, 250
Downing, J. G, and Folan, D W Jun (1953) *New Engl J Med*, 249, 1031.
Gardham, A J. (1953). *Brit J. Surg*, 41, 241
Meyers, E. S. (1953). *Med J Aust*, 2, 957
Windeyer, B W (1953). *Brit J Surg*, 41, 231

MUSCLE AND TENDON—DISEASES AND INJURIES

See also B S P., Vol. 6, p 128, S Key 235.

Herniated intervertebral disc

probabilities can be substantially narrowed by attention to the history, extrinsic ailments,

examination revealed flattened lumbar curves in 87 per cent of the patients, and lateral

are, in general intractable sciatic pain, the development of paralysis in the lower extremity. recurrences which are so frequent or persistent as to be disabling A comparison of surgical methods indicates that, when operative treatment is essential, disc excision alone is preferable to disc excision with spine fusion

Nachlas, I W. (1954) *Med. Pr*, 231, 10

NEW GROWTHS OF TESTIS AND EPIDIDYMIS

See also B S.P., Vol 8, p 183, S. Key 320

Epididymis

Sarcoma

testicle) was noted at the lower pole At operation, the tumour was freed from the scrotal wall, and removed complete with the testicle and cord The post-operative course was

on section.

Benign epithelial tumours

[illegible]

and the appendix epididymis as the sessile and stalked hydatids or as the hydatids of Morgagni, but the description is unsatisfactory as the appendix is solid and the features described as [illegible]

is covered by columnar or cuboidal epithelium. The appendix epididymis was found less frequently and usually on the terminal part of the caput, sometimes sessile and sometimes with a pedicle. Serosal metaplasia was found in many of the specimens examined and occasionally raised cystic lesions were found on the surface of the testis or adnexa. Six tumours were studied which conform to the type of adenomas also called lymphangioma and mesothelioma The most interesting was predominantly tubulo-acinar with a stroma full of vascular fibrous tissue, in some places sedular, hyalinized and devoid of muscle There was a much folded fringe on one side clothed by a single layer of tall columnar epithelium invaginated into the underlying stroma The writer concludes that the oedematous tumours of epididymis arise from the Mullerian vestiges

Eason, T. J., and Soltau, D H K. (1953) *Brit. J. Surg.*, **41**, 331.
Sundarasivarao, D (1953) *J. Path Bact.*, **66**, 417.

OESOPHAGUS

See also B.S P., Vol 6, p 314, S Key 247

Simple tumours

Leiomyoma

Radiographic appearances and thoracotomy.—A case of leiomyoma of the oesophagus is [illegible]

of the left lower lobe and a small effusion, he slowly recovered and had no indigestion. Barium meals gave negative results, but a rounded opacity behind the heart shadow, visible only from certain angles, was detected during screening of the chest. Repetition of the barium swallow demonstrated slight dilatation of the oesophagus in its upper and middle [illegible]

Flavell, G. (1953). *Brit. J. Surg*, **41**, 238

PANCREAS

See also B S P., Vol. 6, p. 433, S Key 257.

Tumours

Hyper-insulinism caused by islet-cell adenoma

Black and co-workers (1954) describe spontaneous hyper-insulinism due to islet-cell adenoma. A tumour of this kind will be quickly fatal if not diagnosed, but operative removal

glucose tolerance test and the rate of removal of intravenous glucose. At operation no pancreatic tumour could be found but part of the organ was removed. No improvement resulted and the symptomalogy changed somewhat, his face often becoming red while he performed aimless movements and was extremely suggestible. At a second operation a pancreatic encapsulated tumour was exposed and on removal was found to be an islet adenoma. The clinical results were excellent In the second patient, a woman of 22, attacks of confusion, sweating and unsteadiness on the legs had been present for about a year At the end of this time she also became unconscious on several occasions On admission to hospital when

cause permanent neurological damage

Black, K. O , Corbett, R. S , Hosford, J P., Turner, J. W A (1954). *Brit. med. J.*, 1, 55.

PEPTIC ULCER AND ITS COMPLICATIONS

See also B S P., Vol 6, p. 496, S. Key 262.

Duodenal ulcer

Vagotomy

Results of operation —Vagotomy as a prophylactic and curative procedure in peptic ulcer is discussed by WALTERS and CHANCE (1953) The operation has been followed by a high recurrence rate for benign gastric ulceration and a high incidence of digestion symptoms, and is to be considered mainly in the treatment of duodenal ulcer, and ulcer recurring after either gastric resection or gastro-enterostomy It is best evaluated by noting its effect on ulcers in which no other operation is performed, especially when the associated operations used to

the operation. The authors excise portions of the nerves, as a routine, for microscopic examination. The results of insulin tests have been normal in many patients with recurrent

Ten-year results —BROOKS and MOORE (1953) present a final survey, after 10 years, of

strectomy

vagotomy

the side-

effects are worse. The efficacy of any surgical treatment of duodenal ulcer depends on the frequency of recurrences and the present study is an effort to ascertain whether empirical results (as measured by recurrence) justifies the continued use of vagotomy. The operation was performed on 137 patients. In the selection of cases, young patients were sought, particularly males, with marked emotional response to their work or surroundings; cases with severe bleeding or obstruction were not considered. Vagotomy alone was performed on 82 patients; vagotomy was combined with posterior gastro-enterostomy in 36 cases and with subtotal gastrectomy in 14 cases. Questionnaires elicited replies from 126 patients; almost half of these had a personal interview, radiographic examination or gastric test. The results indicate that vagotomy alone is not a satisfactory primary surgical treatment for duodenal

gastro-enterostomy. The results substantiate the role of vagotomy in the treatment of

benignity, although
ly in benign ulcers.
found. The grossly
size of the ulcer was

folds still tended to
radiate towards the ulcer crate
number of cases, bear out t
management of gastric ulcer w
nant may be treated as such
by means of multiple diagnostic methods.

Haemorrhage

Haematemesis or melaena

haemorrhage

incidence of both the acute
qual, but there is a 2 : 1 pre-
of men among the chronic gastric ulcer cases. The acute lesions occurred at

to occur in male patients In the ea
thought clinically that an acute ulcer

tomy was performed on 10 patients, of whom 1 died. It is considered probable that if this group had been treated conservatively, 4 of the patients would have died.

Complicated gastric and duodenal ulcer

Surgical care

Gastric resection.—ADAMS and LURIA (1953) describe the surgical care of complicated

patient loads

Radical partial gastrectomy

ment of gastric ulcer patients.

Abbot, F. and Blank, S. (1953) New Engl. J. Med. 249, 722

PLASTIC SURGERY—CORNEAL GRAFTING

See also B.S.P., Vol. 7, p. 50, S. Key 269.

Scope of corneal grafting

Technical, administrative and biological problems

The scope of corneal grafting is discussed by RYCROFT (1954). Since 1906, corneal graft

surgery has made rapid progress, with control of infection, availability of instruments of
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which still remain comprise problems of technique and administration, and biological problems. (1) Technique: (*a*) Fixation of the graft; the author inclines to the old view that the

a clear cornea overlaps Descemet's membrane; a mustard gas cornea shows sharp irregu-
s with
: The
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iterial
vascu-
larisation, and oedema; the investigation and solution of these reactions are of paramount importance in all branches of reconstructive surgery.

Partial penetrating keratoplasty

Use of punch

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paper
s not
easy with the hand or with the mechanical trephine, but he has now devised a punch with jaws the lower jaw being allowed to enter the anterior chamber. The area to be removed

form of a stainless steel tube in which slides a perfectly fitting piston. Part of the lower part of the piston is cut away round its circumference so that the mushroom-like end is attached to the main part by an axial stalk, and the piston is moved up and down by an arm passing along a groove in the cylinder The device is operated by a pair of forceps After making the preliminary incision described, one edge of the punch is slipped under the lower edge of the cut and a piece punched out A similar segment is then removed from the other side
anterior chamber, the stalk
the marked ring

make the

their design

Collection and preservation of the graft

Storage by refrigeration

Freezing in liquid nitrogen.—EASTCOTT and co-workers (1954) describe preservation of corneal grafts by freezing They observe that present methods of storing by refrigeration limits the life of the tissues and unused grafts have to be discarded

results have been good and the method permits storage for indefinite periods

Eastcott, H H G, Cross, A G., Leigh, A G., North, D. P (1954). *Lancet*, 1, 237.
Pittar, C A (1953) *N Z med. J.*, 52, Suppl 22.
Rycroft, B W (1954) *Brit. J Ophthal*, 38, 1

PROSTATE

See also B S P, Vol 7, p. 133, S. Ley 278.

Carcinoma of the prostate

Implantation by biopsy needle

CLARKE, LEADBETTER and CAMPBELL (1953) describe a case in which implantation of prostatic carcinoma cells occurred in the track of a perineal biopsy needle A seventy-year-old man was seen by them 10 months after he had undergone transurethral resection for obstruction He had received stilboestrol therapy, but obstruction had recurred. He had a fixed stony prostate with perivesicular extension, but no other secondary spread, and a normal serum acid phosphatase A carcinomatous biopsy specimen was obtained with a Moonen perineal needle, and castration was performed Stilboestrol was continued, and the obstruction improved However, it recurred again after 10 months, and a further transurethral resection was performed As some portions of the tumour contained areas of squamous metaplasia, radiotherapy was administered Thirteen months after the biopsy had been performed, a 3-millimetre hard nodule appeared in the track of the needle, lying in the subcutaneous tissue There was no other evidence of metastasis, the prostate appeared unchanged, and the patient's general health was good The nodule was accordingly excised, the wound healing soundly without any further local induration The histological picture of the nodule was identical with that of both the needle biopsy and the resection specimens. No previous record has been found in which such an implantation has been noted, although the authors have seen prostatic carcinoma implanted in the abdominal wall after cystoprostatectomy. They advise caution in the selection of cases for perineal needle biopsies

Treatment

Adrenalectomy —Discussing the management of carcinoma of the prostate, CREEVY (1953) refers to the value of removing the adrenal glands The procedure was adopted in the treatment of 5 patients, whose ages ranged from 59 to 74 years Prior to the operation these patients had been castrated and oestrogens had been administered The period of postoperative survival varied from 2½ to 11 months Pain was relieved in 2 cases, but cordotomy was required in the remaining cases As for the literature concerning adrenalectomy for prostatic cancer, 59 cases are recorded but it is emphasized that the treatment has not yet

pressure She died from coronary thrombosis 6 months later. The second patient, a blind woman aged 35 years, died 8 hours after the operation. A haemorrhagic diathesis had been overlooked and death was due to retroperitoneal haemorrhage Death from hypertensive encephalopathy occurred in the fourth case, a man aged 44 years, but the remaining patient, a man aged 43 years, recovered sufficiently to take up part-time work as a hospital physician.

Clarke, B G, Leadbetter, W. F, and Campbell, J S (1953) *J. Urol*, 70, 937.
Creevy, C D (1953). *Canad med. Ass J*, 69, 581

RADIOTHERAPY

Bone tumours

Primary round cell

WALKER and JONES (1953) report on the irradiation management of 5 patients with primary round cell tumours of bone In three patients the original diagnosis of the tumour as a result of clinical and radiological findings and biopsy was Ewing's sarcoma, all three

surgery has made rapid progress, with control of infection, availability of instruments of precision, and safe anaesthesia; selection of cases has become more definite and assessment of results more uniform and accurate. About half the selected patients who undergo full-thickness transplantations may now expect improvement of sight with clear grafts up to 60 per cent, and those for whom the partial-thickness operation is preferred have a higher expectation of improved vision with clear grafts up to about 80 per cent. The difficulties which still remain comprise problems of technique and administration, and biological problems. (1) Technique: (*a*) Fixation of the graft; the author inclines to the old view that the graft should be almost untouched and that fixation should depend on overlay sutures from which the graft is protected by egg membrane; (*b*) cutting the graft; the edge of the graft should be traumatised as little as possible; the author prefers to cut it by the punch method, which compresses the fibres at the edge of the graft; (*c*) selection of cases, a penetrating graft should be used where the scar can be seen by the narrow slit-lamp beam to invade the corneal stroma to the level of Descemet's membrane; lamellar keratoplasty is more suitable when a clear cornea overlaps Descemet's membrane; a mustard gas cornea shows sharp irregularities, causing difficulty when an initial full-thickness graft is used; ocular pemphigus with dry cornea gave unsuccessful results in 8 of the author's cases. (2) Administration: The supply, selection, and preservation of donor material is a problem which is diminishing rapidly, the training of personnel has become a problem, now that adequate donor material is available. (3) Biological problems: These comprise the antibody-antigen reaction, vascularisation, and oedema; the investigation and solution of these reactions are of paramount importance in all branches of reconstructive surgery.

Partial penetrating keratoplasty

Use of punch

PITTAR (1953) describes a method of partial penetrating keratoplasty. He has previously described the trephine guide and corneal splint used for fixing grafts, and in this paper discusses his method of cutting a disc from the recipient's cornea. This procedure is not easy with the hand or with the mechanical trephine, but he has now devised a punch with jaws, the lower jaw being allowed to enter the anterior chamber. The area to be removed is marked out with a trephine and guide, and the ring thus formed is made obvious with fluorescein. The diameter of this ring is incised with a narrow Graefe's knife, which permits introduction of the punch to remove the two halves of the disc in turn. The punch is in the form of a stainless steel tube in which slides a perfectly fitting piston. Part of the lower part of the piston is cut away round its circumference so that the mushroom-like end is attached to the main part by an axial stalk, and the piston is moved up and down by an arm passing along a groove in the cylinder. The device is operated by a pair of forceps. After making the preliminary incision described, one edge of the punch is slipped under the lower edge of the cut and a piece punched out. A similar segment is then removed from the other side and then the whole mushroom end can be introduced into the anterior chamber, the stalk being in the central punched-out area. The punch is now centralized over the marked ring and the whole circumference of the corneal disc is removed in one piece. The graft is then placed in position and a splint in the form of a flat tantalum ring with four grooved projecting arms is secured with corneal sutures. A clear plastic may also be used to make the splint. It is found that the method described makes it far easier to shape the area to receive the graft. Sometimes the punches do not cut completely and it may be possible to improve their design.

Collection and preservation of the graft

Storage by refrigeration

Freezing in liquid nitrogen.—EASTCOTT and co-workers (1954) describe preservation of corneal grafts by freezing. They observe that present methods of storing by refrigeration above the freezing point limits the life of the tissues and unused grafts have to be discarded after a few days. Furthermore, lamellar grafts may have to be cut from the eye *in situ* on the cadaver or from the excised whole eye. Attempts to improve technique of preservation have involved freezing in liquid nitrogen with and without isopentane as an intermediate heat-transfer medium. The grafts, after freezing, were dried *in vacuo* at — 40° C. and were reconstituted by the addition of isotonic sodium chloride. In other experiments the material was stored at — 195° C. for some hours or days. The writers considered the possibility of storing corneal grafts by freezing, using the glycerol-saline technique. They used cadaver material only taken as soon as possible after death and the lamellae were cut from the eye *in situ*. Lamellae and full-thickness grafts were placed in bottles and covered with 15 per cent glycerol in saline solution. After standing 1 hour in room temperature the liquid was decanted, leaving just enough to cover the graft. The screw caps were then tightened and the bottles

were placed in a freezing temperature of 70° C Samples were rapidly thawed before use
esh sterile
isferred to
ts and the
The graft
operative
results have been good and the method permits storage for indefinite periods

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Creevy, C D (1953) *Canad med Ass. J*, 69, 581.

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Bone tumours

Primary round cell

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were treated by irradiation with satisfactory results, and a review of the biopsy material indicates that they were, *in fact*, cases of *reticulum cell* sarcoma. In another patient, an original diagnosis of round cell sarcoma was made; again there was a satisfactory

less prognosis with attendant lack of aggressive therapeutic management in patients with round cell tumours of bone. It is considered that the working diagnosis of round cell tumour of bone in doubtful cases allows for an open mind in the prognosis and the application of therapeutic procedures The authors are convinced that many so-called cures in Ewing's *tumour by either radiotherapy or surgery are actually cures of reticulum cell sarcoma and* other related tumours It seems probable to them that five-year survivals will be reported more frequently by those subscribing to intensive external irradiation.

30 MeV synchrotron

Comparison with the radiotherapeutic methods

MITCHELL (1953) and his colleagues report on their experience with the 30 MeV synchrotron as a radiotherapeutic instrument An account is given of 3 illustrative cases out of

techniques;
tumour to the

The
sues
culty
will be overcome in the course of time The fixed beam is inconvenient. The noise of the

Cregg, H. A., and Smith, F G. (1953). *Radiology*, 61, 379
Mitchell, J. S, Smith, C L., Allen-Williams, D J, and Braams, R. (1953) *Acta radiol, Stockh*, 40, 603.
Turner, J W (1953) *New Engl J. Med*, 249, 507
Walker, J H, and Jones, H. W. (1953) *Radiology*, 61, 738.

RECTUM—CARCINOMA OF

See also B.S.P., Vol. 7, p 325, S Key 290.

Treatment

Radical surgery and radiotherapy

the rectum, basing his observation on a series
of most cases operation was by the single stage,
sigmoidocolostomy using a high peritoneal
abdomino-perineal extirpation in one
local
patients
was

tried in 84 per cent of the operable males and 96 per cent of the operable females In both sexes the largest group was between the ages of 50 to 59. Many patients were beyond any hope of cure when first seen and this was particularly marked in the young men The immediate mortality of the abdomino-perineal operation is greater than that of the perineal

hesitation by the practitioner In those who had had recurrences after radical operations, pain appeared to be more severe than when no operation had been done and it was more easily palliated by x-ray therapy. Colostomy as the only procedure is indicated entirely for obstruction

Rasmussen, T. (1953) *Acta chir scand.*, **106**, 351.

RECTUM—HAEMORRHOIDS

See also B S P , Vol 7, p. 343, S. Key 291.

Haemorrhoidectomy

Wound anaesthesia after operation

analgesics

Lee, M (1954) *Lancet*, **1**, 22

RECTUM—PROLAPSE

See also B S P , Vol 7, p 373, S Key 293.

Treatment

Three types of operation

Dunphy and his colleagues (1953) discuss the results, in 16 cases, of surgical treatment of rectal procidentia Three types of operation were performed: radical perineal excision, radical excision with abdominal repair, suture of the levator muscles with reconstruction of the pelvic floor In the first group of 3 patients, correction of the prolapse and return of sphincter tone were excellent, but in 2 cases, slight redundancy of the rectal mucosa and anterior bulging of the perineum developed within 3 months, necessitating abdominal repair. The same operation, but
performed by Altemeier (1952) w
are good tolerance and satisfact
ticular, gives the best long-time re
operation, it removes the rectum, affects the reflexes and does not preclude recurrence. After describing their original operation (1948) for combined abdomino-perineal excision, the authors discuss their current procedure. An incision to open the perineum is made

anterior to the rectum ...

sutured anterior to it ...

The essential steps are ...

transversalis fascia anterior to the rectum A new pelvic floor is constructed at a higher level The advantages here are cleanliness, relative bloodlessness and speed. The disadvantage is the tendency to post-operative prolapse through the anal canal This operation seems to represent the best anatomical and physiological approach.

Dunphy, J. E., Botsford, T. W , and Savlov, E. (1953). *Amer. J. Surg.*, 86, 605.

SPINAL CORD

See also B S P , Vol 7, p 572, S Key 307

Intramedullary lipoma of spinal cord

Klippel-Feil syndrome

Clinical picture and result of operation.—A case of intramedullary lipoma of the spinal cord associated with the Klippel-Feil syndrome is recorded by Wycis (1953). A woman aged 48 years was admitted to hospital with a history of difficulty in walking and in raising the arms for as long as she could remember; involvement was more marked in the right extremities than the left. All 4 extremities were spastic, especially the lower limbs A ...

[illegible]

vertebra to the foramen magnum. Histological study of a biopsy specimen showed the tumour to be a lipoma. The dura mater was left open to provide full decompression; muscles ... Improvement in walking followed, with ... [illegible] ...ially in the right ... ests that in cases ... tumour.

Wycis, H. T (1953). *J Neurosurg* , 10, 675.

STOMACH—DISEASES OF

See also B S.P , Vol. 8, p 49, S. Key 312.

Gastric operations

... of gastric operations, ... of total gastrectomy, ...

[illegible]

before the present study; in the total gastrectomy group, the period ... operations had ... All the partial-gastrectomy and gastro-enterostomy operations ... astric carcinoma ... ilts showed that, ... per ... omy ... und ... ot severe in any ... ciency anaemia; ... of megaloblastic ...

[illegible]

serious under-nutrition. Only 2 cases of total-gastrectomy showed definite iron-deficiency anaemia; 6 cases had a macrocytic anaemia, and marrow examination, performed in 3 of these, showed "transitional" megaloblasts Evidence of malnutrition was found in 4 per cent of the men and 5 5 per cent of the women in the partial-gastrectomy group, in one of the gastro-enterostomy group, and in 30 per cent of the total-gastrectomy cases The authors consider that these sequelae do not contraindicate operation where it is therapeutically indicated.

Gastrectomy

Indications and results.—An evaluation of the results of gastrectomy, in one surgeon's practice in a community hospital, is presented by BABSON (1953) The experience since 1946 comprises 75 patients, whose ages ranged from 15–88 years The indications for operation included duodenal ulcer, gastric ulcer, massive haemorrhage, cancer, and other diseases;

than 70 per cent of the stomach and the pylorus were removed, in the Billroth I and Hofmeister procedures, all the lesser curvature was included in the resection. A Billroth I

Gastric polyposis

Treatment

DOYLE and his co-workers (1953) report a case of benign gastric polyposis. A man of 54 was admitted with thrombophlebitis of the right leg A long history of epigastric disturbance

gastritis A total gastrectomy with jejunosophagostomy and entero-enterostomy was performed

authors found malignancy in 51 per cent cases Secondary malignant changes have been found in the bladder and liver. The symptoms of the condition vary from a mild gastro-

such as sarcoid or syphilis. The condition has been variously termed Menetrier's disease

ı erroneously called chronic

ıges in the mucosa have no

to be a forerunner to malig-

cosa from elongation of the

otherwise normal glands, the thickening cannot be ascribed to inflammatory infiltration and

helpful results from laboratory study have not been reported. The other conditions already mentioned may produce the same radiographic and gastroscopic appearance Hypoproteinaemia and achlorhydria may be present. The present case was treated by total gastrectomy and splenectomy followed by anastomosis between the oesophagus and duodenum, with uneventful recovery. The stomach measured 17 5 centimetres along the lesser and 48 centimetres along the greater curvature.

Babson, W. W. (1953) *New Engl J Med*, 249, 1101.
Blake, J., and Rechnitzer, P. A (1953). *Quart. J. Med.*, 22, 419.
Doyle, R. T., Nash, H E, and Graham, J H. (1953). *New Engl J. Med.*, 249, 477.
Goodale, F. Junr, and Sniffen, R. C. (1953) *New Engl. J. Med*, 249, 1105.

TABES DORSALIS (LOCOMOTOR ATAXIA)

See also B.S.P, Vol 8, p 169, S. Key 319.

Treatment

surgical intervention It is usually assumed that the primary attack on the nervous system

Many cases treated in this way

its and occasionally of the

protect other joints while

cases surgical excision of

Lees, R. (1953) *Brit. J. vener Dis.*, 29, 198.

THYROID GLAND—DISEASES OF

See also B.S.P, Vol. 8, p. 256, S. Key 327.

Aetiology

been investigated by FERRER

4 5 times as frequently as in the single patients. About one-third of the males were single and less than one-quarter had any progeny The greatest incidence occurred between the ages of 30 and 60 years, the "peak" age being between 40 and 50 years The results of the study demonstrated a relationship between antecedent gonadal disturbance and the aetiology of

castration, hysterectomy, or any other pelvic disease or gonadal surgery, periodic observation should be maintained, so that gonadal replacement or substitution therapy in proper physiological doses may prevent disturbances in thyroid function or form as well as any complications arising from them The study demonstrated a more than coincidental relationship between thyroid disease and pelvic disorders

Treatment

Lesions resulting from radiation

Radio-iodine.—The histological lesions in the thyroid glands of patients receiving radio-

was determined in 18 patients, all had elevated levels prior to therapy Twenty-one of the 23 patients became euthyroid following I^{131} therapy Specimens were obtained in 21 cases at operation, and in 2 at necropsy Examination showed that the glands of 7 patients were predominantly hyperplastic and no definite radiation effects were observed In 9 cases, the specimens showed lesions identical with Hashimoto thyroiditis, this high incidence of
thyr
Has
glar
tissu
folli

associated with injury caused by radiation

Thyroidectomy

Indications.—Mowat (1953) discusses some aspects of thyroidectomy and the thyroid nodule An analysis of 200 cases of thyroid disease, selected at random, revealed 10 instances of primary Graves's disease Thyroidectomy is performed frequently, but it is often difficult, in a particular case, to ascertain what the indications have been The indications for thyroidectomy should be clearly understood Thyrotoxicosis, overt and latent, is diagnosed mainly on: (1) Weight loss in the presence of a good appetite, (2) a warm, moist, skin—not sweating of the palms particularly, as this occurs in any anxiety state, (3) a staring, fixed expression, a feature of Graves's disease rather than of toxic adenoma; (4) the eye

that they are not the cause of the symptoms

Adenoma and carcinoma

Incidence and treatment

CRILE (1953) discusses adenoma and carcinoma of the thyroid gland; he illustrates his article with a diagram of the common zones of lymph node metastasis from cancer of the thyroid. He asserts that statistics on the incidence of cancer in nodular goitre are unreliable because they are based on the selected group of patients whose goitres are removed and

be solitary are usually dominant, involutionary nodules in a multinodular goitre. Distant metastasis and extensive invasion of surrounding structures are distinctly uncommon in papillary cancer of the thyroid gland except in cases in which an incomplete primary operation has been performed

is cut across the loc

incision. The author

of the thyroid. The end results of extensive but carefully planned and non-mutilating operations have been superior cosmetically and functionally and also in affording cure of cancer to those of conventional block dissections

Crile, G. (1953), *New Engl J Med*, 249, 585.
Dailey, M E, Lindsay, S, and Miller, E R. (1953). *J. clin. Endocrin*, 13, 1513.
Ferrer, F P, and McGavack, T. H. (1953) *Amer J Surg*, 85, 67.
Mowat, J. K (1953) *Med J. Aust*, 2, 954

URETER—TRANSPLANTATION OF

See also B.S.P., Vol 8, p 370, S Key 335.

Cord bladder

Management

Practical points in the management of cord bladder are presented by THOMPSON (1953). Cord bladders should be classified only on the basis of efficiency. An efficient bladder is one

for

be re-examined, with excretory urography and cystoscopy. Patients recovering from a cauda equina lesion have been helped by instruction in urinary habits Cases which do not respond to other methods should undergo examination of the neck of the bladder with a view to

resection is indicated in the treatment of any case in which there are repeated episodes of infection of the urinary tract or in which there is extreme difficulty in voiding

Ileo-cystoplasty

Bowel-bladder-wall grafting

Technique and post-operation study and sequelae.—An experimental study of ileo-cystoplasty, using a new technique, is described by TASKER (1953). It appeared that if the bowel could be incorporated in the bladder wall as a flat patch, the resultant increase in volume

would be greater than that achieved by attaching the same piece of bowel as a tubular

closed by using sigmoid colon and omentum and the normal bowel was reconstituted by end-to-end anastomosis in front of the pedicle. The operation was performed on 6 dogs, with no immediate mortality, 1 dog died later from obstruction at the ileo-ileal anastomosis

ry, estimation of
he urine, and the
increased in all
educed to nil in
1 month, showed
iochemical study

demonstrated the risk of potassium intoxication from renal impairment, oliguria, or chronic retention after the catheter has been removed A female patient should be sterilized before grafting to avoid damage to the pedicle in pregnancy Ileo-cystoplasty on a male patient, has given satisfactory results and further improvement is expected

Polythene catheters

Technique of use

The use of polythene catheters in ureteric transplantation is described by DEARING and WAY (1954) Such catheters were made for the writers in 4 sizes and may be sterilized chemically or by boiling with suitable precautions. After dividing the ureter, one end of the

tubes passed urine on the operating table, though more than half those with the tubes did so Nineteen patients in whom the catheters were not used failed to pass urine in the first 24 hours, and of these 10 died, whereas of 16 patients without polythene catheters who urinated in the first day only 4 died. The death rate in the patients in whom the catheters were used was 23 per cent, but in the others 42 per cent Blood urea levels in the two groups illustrate the striking benefit derived from the use of these catheters.

Dearing, R , and Way, S (1954) *Lancet*, 1, 24
Tasker, J H (1953) *Brit J Urol*, 25, 349
Thompson, G. J (1953), *J. Amer med Ass*, 153, 1337

URETHRA—NEW GROWTHS AND STRICTURE

See also B S P , Vol 8, p. 407, S Key 337

Mesothelial tumours of the penis

Vascular endothelial origin

Diagnoses—Mesothelial tumours of the penis have attracted increasing interest in the past 10 years, but only 2 cases of vascular endothelial origin have been seen, and in both of these the tumour was very small HOYT (1953) saw a patient, aged 51, who had had a lump

corpus spongiosum Up to 5½ years later there has been no recurrence

Hoyt, H. S (1953) *J Urol.*, 70, 943.

VASCULAR SURGERY

See also B.S.P., Vol. 8, p. 489, S. Key 343.

Aortic diseases

Arteriosclerotic aneurysms of the abdominal aorta

Thrombo-endarterectomy; homologous grafting; polyvinyl sponge reinforcement.—KIRKLIN and his co-workers (1953) discuss the surgical treatment of arteriosclerotic aneurysms of the abdominal aorta. A series of 23 patients have been treated by 3 different types of operation. (1) Thrombo-endarterectomy and wrapping. This method was used in 4 cases. The thrombus was removed together with the calcified intima and the inner portion of the media; the remaining outer wall of the aneurysm was trimmed, so as to form an essentially normal-sized tube. This was closed with 2 rows of 00000 continuous non-absorbable surgical (silk) sutures after the lumen was filled with heparin solution. The wrapping consisted of fascia lata from the thigh; in the last 2 patients, this was further reinforced with polyvinyl sponge (Ivalon). In the last 3 patients, bilateral lumbar sympathectomy was performed after aortic mobilization and before the aorta was clamped. (2) Resection and replacement by a preserved homologous aortic graft was performed in 1 case. In this operation, the difficult phase of the dissection, that is, the separation of the aneurysm from the inferior vena cava and the left common iliac vein, was deferred until proximal and distal clamps had been applied; again, bilateral lumbar sympathectomy was performed just before the aorta was clamped. (3) Reinforcement with polyvinyl sponge was carried out in 18 cases. The operation, performed in this series, is not extensive; in most cases, no attempt was made to separate the aneurysm from the vena cava or to mobilize it posteriorly, as in this procedure there is little chance to reinforce or control any tears made into the aorta during dissection. Thin plaques of sponge were laid against all exposed surfaces of the aneurysm and sutured into place. Of the 23 patients treated there were 3 deaths: 2 occurred among the cases treated by reinforcement with polyvinyl sponge (1 from renal failure and the other from massive thrombotic occlusion of the iliac arteries immediately post-operatively, necessitating a second operation 10 hours after the first); 1 of the patients on whom thrombo-endarterectomy was performed died in the immediate post-operative period, this patient had a huge leaking aneurysm, and diffuse arteriosclerosis was present in the abdominal aorta and iliac vessels; arterial insufficiency developed rapidly in the left leg, and gangrene was apparent at the time of the patient's death from cardiac failure. Treatment by reinforcement with polyvinyl sponge, or by thrombo-endarterectomy, has, so far, given disappointing over-all results, although the former method has provided relief of pain in 44 per cent of the survivors. The immediate results in the cases treated by resection and graft have been excellent, the patient having had a satisfactory convalescence, with normal pulses in both legs at all times.

Coronary disease

Surgical measures

MURRAY (1943) and his co-workers discuss the surgery of coronary disease. Measures might be divided into: (1) Symptomatic treatment, and (2) direct attack on coronary arteries or heart muscle to correct the cardiac physiology by dealing with the particular lesion. The methods used in symptomatic treatment have included. Dissecting the cervical sympathetic; alcohol block, and resection of dorsal ganglia with intervening segments. The direct attack has included. Denervation of the coronary arteries by sharp dissection, followed by chemical sclerosis of the plexus; tying the coronary sinus, and suturing grafts of adjacent vascular structures to areas of ventricular wall. Transplantation of the distal end of the divided internal mammary artery into the left ventricular wall has given promising results experimentally; the author has operated on 4 patients with excellent results in 3. The problem of resection of part of the coronary artery, filling the gap with grafts, has been investigated; the author has completed experiments on dogs, in which, by perfusion of the distal segment of the coronary artery, successful repair was possible without infarct formation. The perfusion was performed by passing a plastic tube through a branch of the divided internal mammary artery, subclavian or other artery, or a graft from one of these vessels, and having the tube project through the end of the artery. Three of 13 dogs survived, with no infarction. Successful anastomosis was then performed easily; 8 of 17 dogs survived and did well after the operation. Investigation has shown that an area of the heart loses contractility following ligation of the coronary artery, and the author has obtained improved results by resection of this area, with suturing of the contractile muscle on one side of the defect to the good contractile muscle on the other edge.

Venous thrombosis

Tying inferior vena cava

Indications.—PAYNE (1953) discusses indications for tying the inferior vena cava in venous

thrombosis Twenty years ago the surgical approach to thrombophlebitis complicated by

anti-coagulants developed they were used more freely, but to get good results extreme attention to detail is essential, and treatment outside hospital is unsatisfactory. Although thrombophlebitis may be best treated by these preparations, difficulty arises when a pulmonary embolus occurs For many years ligation of the inferior vena cava has been done in these circumstances, and the writer studied 59 patients suffering from severe venous thrombosis with or without emboli In 7 of these inferior vena caval ligation was performed or advised. The first patient was a man of 56 who developed pain in the right leg just above the knee which later spread to the groin, the whole leg becoming discoloured There was a history of pulmonary embolism after appendicectomy 15 years before Anti-coagulants were used as the peripheral arterial pulsation was good in both legs, but some days after admission sudden and severe chest pain was felt and a little later another attack of pain in the same area indicated that surgical intervention was needed The inferior vena cava was isolated

Kirklin, J. W, Wough, J M, Grindlay, J H, Openshaw, C R., and Allen, E. V. (1953). *Arch Surg, Chicago*, 67, 632
Murray, G, Hilario, J, Porcheron, R, and Roschlau, W (1953) *Angiology*, 4, 526
Payne, J T (1953) *Arch Surg, Chicago*, 67, 902

VITAMINS AND NUTRITION IN RELATION TO SURGERY

See also B S.P, Vol 8, p 565, S Key 347

Fat supplements

9 critically ill selected patients, all of whom showed striking weight loss, progressive debility, a febrile course, and complications such as decubitae and mental changes Average intakes during a control period, in which patients received the regular hospital diet or a variation,

and water All the 9 cases showed improvement in both nutrition and general status, increase in general strength, sense of well-being, and morale There was a more rapid healing of wounds, and decrease in size, or disappearance, of decubitae previously resistant to any therapy The temperature, in pyrexial cases, became normal. There were no ill-effects from the fat emulsion, and gastro-enteric complaints were minimal. All the patients were able to ingest at least 100 cubic centimetres of the mixture 3 times daily; 1 patient received 600 cubic centimetres daily for 90 days without complaint The development of nausea in 1 patient, and of mild diarrhoea in another, may have been attributable to drugs which were being given simultaneously

Mindrum, G. M. (1953) *J Nutr*, 1, 503

NOTER-UP, 1954

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